markable phenomena bearing directly on the nature of enhanced lines in general, which he describes in the present communication. Using larger dispersion than in his former experiments, and employing thinner tubes in the furnace, he ran the furnace until the tube wore thin with the strong vaporisation of the carbon, and ultimately broke. It was near this breaking period that the important observations were made.

The description of the experiments is given very fully in the paper, and is finely illustrated with reproductions of some of the spectra obtained, but here only the leading features of the research can be stated. The titanium enhanced lines appear in the regular furnace spectrum for temperatures probably somewhat higher than 2000° C., but are very faint compared with the arc lines. At still higher temperatures, the furnace conditions still existing, there is an indication of a slight increase in the relative strength of the enhanced lines. At the stage when the furnace tube burns through, resulting in the formation of a low-voltage arc, the consumption of electrical energy at the point being very large, the enhanced lines of titanium and the spark line λ4267 of carbon appear with an intensity usually attainable only in powerful sparks. Photographs taken with the slit across the entire image of the tube's interior show that the relative strength of the enhanced lines is much greater in the centre of the tube than near the wall, the effect being very pronounced in the case of the carbon spark line. Mr. King also directs attention to the important observation that the vapour in the centre of the broken tube shows a tendency to give a line farther to the red than near the wall, this being shown in the increasing dissymmetry of the lines from the end towards the middle. This effect, he points out, is in harmony with the action of the condensed spark, but can scarcely, in the case of the furnace lines, be ascribed to pressure.

ARISTOTLE AS A NATURALIST.[1]

AMONG the isles of Greece there is a certain island, *insula nobilis et amoena*, which Aristotle knew well. It lies on the Asian side, between the Troad and the Ionian coast, and far into its bosom, by the little town of Pyrrha, runs a broad and sheltered lagoon. It is the island of Lesbos. Here Aristotle came and spent two years of his life, in middle age, bringing his princess-bride from the petty court of a little neighbouring State where he had already spent three years. It was just before he went to Macedon to teach Alexander; it was ten years later that he went back to Athens to begin teaching in the Lyceum. Now in the "Natural History," references to places in Greece proper are very few indeed; there is much more frequent mention of places on the northern and eastern coasts of the Ægean, from Aristotle's own homeland down to the Carian coast; and to places in and round that island of Lesbos or Mytilene, a whole cluster of Aristotle's statements and descriptions refer. Here, for instance, Aristotle mentions a peculiarity of the deer on a neighbouring islet, of the weasels by the wayside by another island town. He speaks of the big purple Murex shells at Cape Lectum, and of the different sorts of sponges found on the landward and the seaward side of Cape Malia. But it is to the lagoon at Pyrrha that Aristotle oftenest alludes. Here were starfish, in such abundance as to be a pest to the fishermen; here the scallops had been exterminated by a period of drought, and by the continual working of the fishermen's dredge; here the sea-urchins come into season in the winter time, an unusual circumstance. Here among the cuttlefishes was found no octopus, either of the common or of the musky kind; here was no parrot-wrasse, nor any kind of spiny fish, nor sea-crawfish, nor the spotted nor the spiny dog-fish; and, again, from this lagoon, all the fishes, save only a little gudgeon, migrated seaward to breed. And though with no special application to the island, but only to the Asiatic coast in general, I may add that the chameleon, which is the subject of one of Aristotle's most perfect and minute investigations, is here comparatively common, but is not known to occur in Greece at all.

I take it then as probable, or even proven, that an important part of Aristotle's work in natural history was done upon the Asiatic coast, and in and near to Mitylene. He will be a lucky naturalist who shall go some day and spend a quiet summer by that calm lagoon, find there all the natural wealth ὅσσον Λέσβος . . . ἐντὸς ἐέργει, and have around his feet the creatures that Aristotle loved and knew. Moreover, it follows for certain, if all this be true, that Aristotle's biological studies preceded his more strictly philosophical work; and it is of no small importance that we should be (so far as possible) assured of this, when we speculate upon the influence of his biology on his philosophy.

Aristotle is no tyro in biology. When he writes upon mechanics or on physics, we read him with difficulty: his ways are not our ways; his explanations seem laboured; his science has an archaic look, as it were coming from another world to ours, a world before Galileo. Speaking with all diffidence, I have my doubts as to his mathematics. In spite of a certain formidable passage in the "Ethics," where we have a sort of *ethica more geometrico demonstrata*, favourite use of the equality of the angles of a triangle to four right angles, as an example of proof indisputable, in spite even of his treatise, "De Lineis Insecabilibus," I am tempted to suspect that he sometimes passed shyly beneath the superscription over Plato's door.

But he was, and is, a very great naturalist. When he treats of natural history, his language is our language, and his methods and his problems are well-nigh identical with our own. He had familiar knowledge of a thousand varied forms of life, of bird, and beast, and plant, and creeping thing: he was careful to note their least details of outward structure, and curious to probe by dissection into their parts within. He studied the metamorphoses of gnat and butterfly, and opened the bird's egg to find the mystery of incipient life in the developing chick. He recognised great problems of biology that are still ours to-day, problems of heredity, of sex, of nutrition and growth, of adaptation, of the struggle for existence, of the orderly sequence of nature's plan. Above all, he was a student of life itself. If he was a learned anatomist, a great student of the dead, still more was he a lover of the living. Evermore his world is in movement. The seed is growing, the heart beating, the frame breathing. The ways and habits of living things must be known: how they work and play, love and hate, feed and procreate, rear and tend their young; whether they dwell solitary, or in more and more organised companies and societies. All such things appeal to his imagination and his diligence. Even his anatomy becomes at once an *anatomia animata*, as Haller, poet and physiologist, was wont to describe the science to which he gave the name of physiology. This attitude towards life, such knowledge got thereby, afterwards helped to shape and mould Aristotle's philosophy.

I have no reason to suppose that the study of biology "maketh a man wise," but I am sure it helped

[1] From the Herbert Spencer lecture delivered at Oxford on February 14 by Prof. D'Arcy W. Thompson, C.B.

to lead Aristotle on the road to wisdom. Nevertheless he takes occasion to explain, or to excuse, his devotion to this study, alien, seemingly, to the pursuit of philosophy. "Doubtless," he says, "the glory of the heavenly bodies fills us with more delight than we gain from the contemplation of these lowly things; for the sun and stars are born not, neither do they decay, but are eternal and divine. But the heavens are high and afar off, and of celestial things the knowledge that our senses give us is scanty and dim. On the other hand, the living creatures are nigh at hand, and of each and all of them we may gain ample and certain knowledge if we so desire. If a statue please us, shall not the living fill us with delight; all the more if in the spirit of philosophy we search for causes and recognise the evidences of design. Then will nature's purpose and her deep-seated laws be everywhere revealed, all tending in her multitudinous work to one form or another of the beautiful." In somewhat similar words does Bacon retranslate a familiar saying: "He hath made all things beautiful according to their seasons; also he hath submitted the world to man's enquiry." On the other hand, a most distinguished philosopher of to-day is struck, and apparently perplexed, by "the awkward and grotesque, even the ludicrous and hideous forms of some plants and animals." I commend him, with all respect, to Aristotle—or to that Aristotelian verity given us in a nutshell by Rodin, "Il n'y a pas de laideur!"

To be sure, Aristotle's notion of beauty was not Rodin's. He had a philosopher's comprehension of the beautiful, as he had a great critic's knowledge and understanding of poetry; but wise and learned as he was, he was neither artist nor poet. His style seldom rises, and only in a few such passages as that which I have quoted, above its level didactic plane. Plato saw philosophy, astronomy, even mathematics, as in a vision; but Aristotle does not know this consummation of a dream. The bees have a king, with Aristotle. Had Plato told us of the kingdom of the bees, I think we should have had Shakespearian imagery. The king would have had his "officers of sorts," his magistrates, and soldiers, his "singing masons building roofs of gold." Even Pliny, arid encyclopædist as he is, can now and then throb and thrill us as Aristotle cannot do—for example, when he throws no little poetry and still more of music into his description of the nightingale's song.

But let us now come, at last, to exemplify, by a few brief citations, the nature and extent of Aristotle's zoological knowledge. Among the bloodless animals, as Aristotle called what we call the invertebrates, he distinguishes four great genera, and of these the Molluscs are one. These are the cuttle-fish, which have now surrendered their Aristotelian name of "molluscs" to that greater group, which is seen to include them, with the shellfish, or "ostracoderma" of Aristotle. These cuttle-fishes are creatures that we seldom see, but in the Mediterranean they are an article of food, and many kinds are known to the fishermen. All, or well-nigh all, of these many kinds were known to Aristotle, and his account of them has come down to us with singular completeness. He describes their form and their anatomy, their habits, their development, all with such faithful accuracy that what we can add to-day is of secondary importance. He begins with a methodical description of the general form, tells us of the body and fins, of the eight arms with their rows of suckers, of the abnormal position of the head. He points out the two long arms of Sepia and of the Calamaries, and their absence in the octopus; and he tells us, what was only confirmed of late, that with these two long arms the creature clings to the rock and sways about like a ship at anchor. He describes the great eyes, the two big teeth forming the beak; and he dissects the whole structure of the gut, with its long gullet, its round crop, its stomach, and the little coiled coccal diverticulum; dissecting not only one but several species, and noting differences that were not observed again until Cuvier redissected them. He describes the funnel and its relation to the mantle-sac, and the ink-bag, which he shows to be largest in Sepia of all others. And here, by the way, he seems to make one of those apparent errors that, as it happens, turn out to be justified; for he tells us that in Octopus the funnel is on the upper side, the fact being that when the creature lies prone upon the ground, with all its arms spread and flattened out, the funnel-tube (instead of being flattened out beneath the creature's prostrate body) is long enough to protrude upwards between arms and head, and to appear on one side or other thereof, in a position apparently the reverse of its natural one. He describes the character of the cuttle-bone in Sepia, and of the horny pen which takes its place in the various calamaries, and notes the lack of any similar structure in Octopus. He dissects in both sexes the reproductive organs, noting without exception all their essential and complicated parts; and he had figured these in his lost volume of anatomical diagrams. He describes the various kinds of eggs, and, with still more surprising knowledge, shows us the little embryo cuttle-fish, with its great yolk-sac, attached (in apparent contrast to the chick's) to the little creature's developing head.

But there is one other remarkable feature that he knew ages before it was rediscovered, almost in our own time. In certain male cuttle-fishes, in the breeding season, one of the arms develops in a curious fashion into a long coiled whip-lash, and in the act of breeding may then be transferred to the mantle-cavity of the female. Cuvier himself knew nothing of the nature or the function of this separated arm, and, indeed, if I am not mistaken, it was he who mistook it for a parasitic worm. But Aristotle tells us of its use and its temporary development, and of its structure in detail, and his description tallies closely with the accounts of the most recent writers.

Among the rarer species of the group he knew well the little Argonaut, with its beautiful cockle-shell, and tells how it puts up its two broad arms to sail with, a story that has been rejected by many, but that, after all, may perhaps be true.

Now in all this there is far more than a mass of fragmentary information gleaned from the fishermen. It is a plain orderly treatise, on the ways and habits, the varieties, and the anatomical structure, of an entire group. Until Cuvier wrote there was none so good, and Cuvier lacked knowledge that Aristotle possessed.

As exact and scarce less copious is the chapter in which Aristotle deals with the crab and lobster, and all such crustacean shell-fish, and that in which he treats of insects, after their kind. Most wonderful of all, perhaps, are those portions of his books in which he speaks of fishes, their diversities, their structure, their wanderings, and their food. Here we may read of fishes that have only recently been rediscovered,[2] of structures only lately re-investigated, of habits only of late made known.[3] And many such anticipations of our knowledge, and many allusions to things of which perhaps we are still ignorant, may yet be brought to light; for we are still far from having

[2] *E.g. Parasilurus aristotelis*, a siluroid fish of the Achelous.
[3] *E.g.* the reproduction of the pipe-fish-s (Syngnathi), the hermaphrodite nature of the Serrani, the nest-building of the wrasses, &c.

interpreted and elucidated the whole mass of Aristotle's recorded erudition, which whole recorded mass is only, after all, *tanquam tabula naufragii*.

There is perhaps no chapter in the "Historia Animalium" more attractive to the anatomist than one which deals with the anatomy and mode of reproduction of the cartilaginous fishes, the sharks and rays, a chapter which moved to admiration that prince of anatomists Johannes Müller.[4] The latter wrote a volume on the text of a page of Aristotle, a page packed full of a multitude of facts, in no one of which did Johannes Müller discover a flaw. The subject is technical, but the gist of the matter is this: that among these Selachians (as, after Aristotle, we still sometimes call them) there are many diversities in the structure of the parts in question, and several distinct modes in which the young are brought forth or matured. For in many kinds an egg is laid, which eggs, by the way, Aristotle describes with great minuteness. Other kinds do not lay eggs, but bring forth their young alive, and those include the torpedo and numerous sharks or dogfish. The eggshell is in these cases very thin, and breaks before the birth of the young. But among them there are a couple of sharks, of which one species was within Aristotle's reach, where a very curious thing happens. Through the delicate membrane, which is all that is left of the eggshell, the great yolk-sac of the embryo becomes connected with the parental tissues, which infold and interweave with it; and by means of this temporary union the blood of the parent becomes the medium of nourishment for the young. And the whole arrangement is physiologically identical with what obtains in the higher animals, the mammals, or warm-blooded vivipara. It is true that the yolk-sac is not identical with that other embryonic membrane which comes in the mammals to discharge the function of which I speak; but Aristotle was aware of the difference, and distinguishes the two membranes with truth and accuracy.

It happens that of the particular genus of sharks to which this one belongs, there are two species differing by almost imperceptible characters; but it is in one only of the two, the γαλεὸς λεῖος of Aristotle, that this singular phenomenon of the *placenta vitellina* is found. It is found in the great blue shark of the Atlantic and the Mediterranean; but this creature has grown to a very large size before it breeds, and such great specimens are not likely to have come under Aristotle's hands. Cuvier detected the phenomenon in the blue shark, but paid little attention to it, and for all his knowledge of Aristotle, did not perceive that he was dealing with an important fact which the philosopher had studied and explained. In the seventeenth century, the anatomist Steno actually rediscovered the phenomenon, in the γαλεὸς λεῖος, the *Mustela laevis* itself, but he was unacquainted with Aristotle. And the very fact was again forgotten until Johannes Müller brought it to light, and showed not only how complete was Aristotle's account, but how wide must have been his survey of this class of fishes to enable him to record this peculiarity in its relation to their many differences of structure and reproductive habit. I used to think of this phenomenon as one that Aristotle might have learned from the fishermen, but after a more careful study of Johannes Müller's book, I am convinced that this is not the case. It was a discovery that could only have been made by a skilled and learned anatomist.

[4] *Cf.* Cavolini, in his classical 'Mem. sulla Generazione dei Pesci," Naples, 1787: "E quando io . . . scorro la Storia degli Animali di Aristotile, non posso non essere da stupore preso, in esse leggende veduti quei fatti, che a noi non si son potuti che a stento manifestare: e rilevati poi con tutta la nettezza, e posti in parallelo coi fatti già riconosciuti nel feto del gallo;" &c.

In a lengthy and beautiful account Aristotle describes the development of the chick. It is on the third day that the embryo becomes sufficiently formed for the modern student to begin its study, and it was after just three days (a little earlier, as Aristotle notes, in little birds, a little later in larger ones) that Aristotle saw the first clear indication of the embryo. Like a speck of blood, he saw the heart beating, and its two umbilical blood-vessels breaking out over the yolk. A little later he saw the whole form of the body, noting the disproportionate size of head and eyes, and found the two sets of blood-vessels leading, the one to the yolk-sac, the other to the new-formed allantois. In the tiny chick of the tenth day, he saw the stomach and other viscera; he noted the altered position of the heart and great blood-vessels; he traced clearly and fully the surrounding membranes; he opened the little eye, to seek, but failed to find, the lens. And at length he describes in detail the appearance and attitude of the little chick, the absorption of the yolk, the shrivelling of the membranes, just at the time when the little bird begins to chip the shell, and before it steps out into the world. While this account contains but a part of what Aristotle saw (and without a lens it would be hard to see more than he), it includes the notable fact of the early appearance of the heart, the *punctum saliens* of later writers, whose precedence of all other organs was a chief reason for Aristotle's attributing to it a common, central, or primary sense, and so locating in it the central seat of the soul. And so it was held to be until Harvey's time, who, noting the contemporaneous appearance of heart and blood, held that the contained was nobler than that which contained it, and that it was the blood that was "the fountain of life, the first to live, the last to die, the primary seat of the soul, the element in which, as in a fountain-head, the heat first and most abounds and flourishes"; so harking back to a physiology more ancient than Aristotle's—"for the blood is the life thereof." All students of the "Timaeus" know that here Aristotle parted company with Plato, who, following Hippocrates and Democritus, and others, placed the seat of sensation, the sovereign part of the soul, in the brain. Right or wrong, it was on observation, and on his rarer use of experiment,[5] that Aristotle depended. The wasp or the centipede still lives when either head or tail is amputated, the tortoise's heart beats when removed from the body, and the heart is the centre from which the blood-vessels spring. To these arguments Aristotle added the more idealistic belief that the seat of the soul, the ruling force of the body, must appropriately lie in the centre; and he found further confirmation of this view from a study of the embryo plant, where in the centre, between the seed-leaves, is the point from which stem and root grow. And Ogle reminds us how, until a hundred years ago, botanists still retained an affectionate and superstitious regard for that portion of the plant, calling it now *cor*, now *cerebrum*, the plant's heart or brain.

And now is it possible to trace directly the influence of Aristotle's scientific training and biological learning upon his sociology, his psychology, or in general on his philosophy? That such an influence must have been at work is, *prima facie*, obvious. The physician who becomes a philosopher will remain a physician to the end; the engineer will remain an engineer; and the ideas of pure mathematics, Roger Bacon's "alphabet of philosophy," will find issue and expression in the philosophy of such mathematicians as

[5] Aristotle's experiments were akin to Voltaire's, who employed himself in his garden at Ferney in cutting off the horns and heads of snails, to see whether, or how far, they grew again.

Plato, Leibnitz, Spinoza, or Descartes. Moreover, it is not only the special training or prior avocation of the philosopher that so affects his mind. In divers historical periods the rapid progress or the diffused study of a particular science has moulded the philosophy of the time. So on a great scale in the present day does biology; so did an earlier phase of evolutionary biology affect Hegel; and in like manner, in the great days of Dalton and Lavoisier, did chemistry help, according to John Stuart Mill, to suggest a "chemistry of the mind" to the "association" psychologists? A certain philosopher,[6] in dealing with this theme, begins by telling us that "Mathematics was the only science that had outgrown its merest infancy among the Greeks." Now it is my particular purpose to-day to show, from Aristotle, that this is not the case. Whether Aristotle's biological forerunners were many or few, whether or not the Hippocratics (for instance) had failed to raise physiology and anatomy to the dignity of a science, or, having done so, had only reserved them, as a secret cult, to their own guild; in short, whether Aristotle's knowledge is in the main the outcome of his solitary labours, or whether, as Leibnitz said of Descartes, *praeclare in rem suam vertit aliorum cogitata*, it is at least certain that biology was in *his* hands a true and comprehensive science only second to the mathematics of his age.

The influence, then, of scientific study, and in particular of biology, is not far to seek in Aristotle's case. It has ever since been a course or plan to compare the State, the body politic, with an organism, but it was Aristotle who first employed the metaphor. Again, in his exhaustive accumulation and treatment of facts, his method is that of the observer, of the scientific student, and is in the main inductive. Just as, in order to understand fishes, he gathered all kinds together, recording their forms, their structure, and their habits, so he did with the constitutions of cities and of States. Those two hundred and more πολιτεῖαι which Aristotle laboriously compiled, after a method of which Plato would never have dreamed, were to form a natural history of constitutions and governments. And if we see in his concrete, objective treatment of the theme a kinship with Spencer's descriptive sociology, again, I think, a difference is soon apparent between Spencer's colder catalogue of facts and Aristotle's more loving insight into the doings and into the hearts, into the motives and the ambitions, of men.

But whatever else Aristotle is, he is the great Vitalist, the student of the body with the life thereof, the historian of the soul.

Now we have already seen how and where Aristotle fixed the soul's seat and local habitation. But the soul has furthermore to be studied according to its attributes, or analysed into its "parts." Its attributes can be variously analysed, as in his "Ethics" Aristotle shows. But it is in the light of biology alone that what amounts to a scientific analysis, such as is developed in the "De Anima," becomes possible; and in that treatise, it is only after a long preliminary physiological discussion that Aristotle at length formulates his distinctive psychology. There is a principle of continuity, a συνέχεια that runs through the scale of structure in living things, and so, little by little, by imperceptible steps, does nature make the passage from plant, through animal, to man: it is with all the knowledge summarised in a great passage of the "Natural History," and embodied in this broad generalisation, that he afterwards proceeds to indicate the same gradation in psychology, and to draw from it a kindred classification of the soul.

[6] Ritchie, "Darwin and Hegel," p. 39.

But observe that, though Aristotle follows the comparative method, and ends by tracing in the lower forms the phenomena incipient in the higher, he does not adopt the method so familiar to us all, on which Spencer insisted, of first dealing with the lowest, and of studying in successive chronological order the succession of higher forms. The historical method, the realistic method of the nineteenth century, the method to which we insistently cling, is not the only one. Indeed, even in modern biology, if we compare, for instance, the embryology of to-day with that of thirty years ago, we shall see that the pure historical method is relaxing something of its fascination and its hold. Rather has Aristotle continually in mind the highest of organisms, in the light of the integral and constituent phenomena of which must the less perfect be understood. So was it with one whom the Lord Chancellor of England has called "the greatest master of abstract thought since Aristotle died." For Hegel, as I feel sure for Aristotle, *Entwicklung* was not a "time-process but a thought-process." To Hegel, an actual, realistic, outward, historical evolution seemed but a clumsy and materialistic philosophy of nature. In a sense, the "time-difference has no interest for thought." And if the lower animals help us to understand ourselves, it is in a light reflected from the study of man.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

CAMBRIDGE.—At a meeting of the electors to the Plumian professorship of astronomy held on April 19 Mr. A. S. Eddington, chief assistant at the Royal Observatory, Greenwich, was elected into the professorship, in succession to the late Sir George Darwin.

The adjudicators of the Adams Prize for the period 1911–12 consider that the two essays submitted to them with the following titles are of distinction: "The Theory of Radiation," by Mr. S. B. McLaren, and "The Fundamental Spectra of Astrophysics," by Dr. J. W. Nicholson, between whom the prize is divided in equal shares.

OXFORD.—The Romanes lecture will be delivered on Thursday, May 8, at 3 p.m., by Sir W. M. Ramsay. The subject is "The Imperial Peace: an Ideal Pervading European History."

The Halley lecture will be delivered on Thursday, May 22, at 8.30 p.m., by Dr. Louis A. Bauer, of the Carnegie Institution of Washington, U.S.A. Subject, "The Earth's Magnetism." The lecture will be illustrated by lantern slides.

On Tuesday, April 22, Convocation authorised the expenditure of a sum not exceeding 6000*l.* for the erection of additional buildings forming an extension of the School of Rural Economy. The money will be provided partly by a grant from the Development Fund of the Treasury, and partly out of the sum presented to the University in 1912 by Mr. Walter Morrison for the promotion of the study of agriculture.

UNDER the title *Educação*, a new fortnightly twelve-page magazine has been started in Portugal, dealing with elementary education, and we have now received the current issues, which commence with January. It contains original articles and reviews, an interesting feature being the series of experiments in elementary physics classed under two categories, namely experiments performed with simple apparatus (such as coffee-pots, kitchen utensils, and the like) and experiments suited for a laboratory.