Aristotle's treatise known as the Physics, is actually an introduction to the study of nature as a whole: to Physics in the more recent sense, inasmuch as its aim is to approach the general laws that govern the universe (which Aristotle had attempted in the De Caelo, a treatise on the universe as a whole), as well as to the study of life in nature, including man himself. Book I of the Physics bears on what, in general, the study of nature is about, and what are the essential conditions of the subject that is its own. Book II is concerned with the method to be followed in the study of nature as well as with its limitations; this is still very general, for each particular department of natural science has a method more peculiar to it,(1) which is gradually established through practice and therefore more and more dependent on the evolution of that particular branch of science.

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(1) St. Thomas, In II Metaph., lect. 5, n. 335: "...Quia diversi secundum diversos modos veritatem inquirunt; ideo oportet quod homo instruatur per quem modum in singulis scientiis sint recipienda ea quae dicuntur.— Et quia non est facile quod homo simul duo capiat, sed dum ad duo attendit, neutrum capere potest; absurdum est, quod homo simul quaerat scientiam et modum qui convenit scientiae. Et propter hoc debet prius addiscere logicam quam alias scientias, quia logica tradit communem modum procedendi in omnibus aliis scientiis. Modus autem proprius singularum scientiarum, in scientiis singulis circa principium tradi debet."

Chapter I

THE KIND OF SCIENCE HERE TO BE STUDIED.

St. Thomas prepares us for the study of Aristotle's natural philosophy by means of a general preface which, although only a few paragraphs long, is of such vital importance that it seems well both to quote it in full, and to offer the beginner some assistance in seizing the main ideas which it contains. The first paragraph might be translated as follows:

"Since the treatise called the Physics, which it is our "purpose to explain, is also the one that comes first in the study "of nature, we must show, at its very beginning, what natural "science is about — viz. its matter and subject. To this end, "we should point out, on the one hand, that inasmuch as every "science is in the intellect, and since a thing becomes intelligible "in act insofar as it is more or less abstracted from matter, things, "according as they are diversely related to matter, are the concern "of different sciences. Again, since science is obtained by "demonstration, and the middle term of demonstration is the "definition, it follows, of necessity, that the sciences will be "distinguished according to a difference in their mode of definition."(1)

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(1) In the Leonine edition, St. Thomas's own introduction comprises nn. 1 to 4 of Lesson I. - The recent manual edition of A.-M. Pirotta, O.P., numbers the paragraphs of the entire commentary from 1 to 2550. In the margin of this work we refer to the division of St. Thomas's text of the Leonine edition and, between parenthesis, to the numbers of the Pirotta's manual text.

1. Some meanings of the term science.

In the very first sentence of this paragraph several terms are used which require some attention here. They have already been treated in Logic, but it will be useful to call to mind certain principles regarding the nature of our thinking which simply must be grasped before we can hope to understand the kind of science that we are now being invited to study.

Because the word science is frequently used to signify widely different kinds of knowledge, and since St. Thomas, in this context, has in mind only one kind, we must first point out what this is. When a single word is currently used to mean different things whose relationship is not clear on first sight, it may be useful to point out an example of something which, pertaining to the same general field — such as 'knowledge' — is manifestly not an instance of any of its recognized meanings. E.g., the knowledge that Socrates is now standing at that corner of this street may be very certain to him, or to someone else who sees him there, but we are not in the habit of calling this kind of knowledge 'science'. The reason is not that it is merely knowledge of a strictly individual fact, for some such facts are said to have been established in a scientific way. When a historical fact has been ascertained as the result of an orderly approach, complying with definite rules that are susceptible of being verified — e.g. that Aristotle was not the author of the Liber de causis — we are wont to call this knowledge "scientific". We all know what is meant when one historian is called 'more scientific' than some other who takes hearsay for fact. It is futile to quarrel over the use of the word 'science' in connection with such knowledge, and far better to enquire why it is actually so used. Again, of the observed relationship between the tides and the phases of the moon, or between the behaviour of people and the weather (comprising such items as suns and constellations), we say that they are scientifically certain. When the makers of cigarettes announce that their particular brand has been 'scientifically tested', they mean to refer to a process of examination performed according to accepted rules. "Any mode of investigation by which scientific or other impartial and systematic knowledge is acquired" is the description of Scientific Method found in an article under this heading in the Encyclopaedia Britannica.

All this suggests that the term 'science' has to do with knowledge obtained by some recognized means or process emphasized as impartial. It is implied that anyone who can grasp the means or can understand the process, ought to agree that what is discovered or proved by it, deserves his assent.

Among the studies called sciences, mathematical physics is often presented as so ideal in method and standards that the other departments of the study of nature are called scientific only in the measure that they approach its exactness. Now, what we must notice is that, if mathematical physics is called the most exact, it is because it attains more closely to the precision of mathematics itself, which is undoubtedly more rigourous than any other science. In fact, when Aristotle mentions the 'disciplines' without qualification, he means mathematics.

2. An example of mathematical science.

If mathematics is science in the truest sense and so recognized in every age, it should make a safe beginning to choose a mathematical example as our first guide towards learning what is the kind of knowledge wirh reference to which other kinds are called scientific in the measure that they approach or resemble it. Take the following statement in the context of Euclidian geometry: 'The sum of the angles of any triangle is two right angles'. Now this proposition is not self-evident: it follows from reasons already known but not contained in the proposition itself. How is his reason established? and how do we proceed from it to that proposition which is its conclusion? Euclid has resort to the following proof: (2)

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(2) Book I, Theorem 32. The Thirteen Books of Euclid's Elements, translated by Sir Thomas Heath, Cambridge University Press, 1926, 3 vol.

In geometry, demonstrations should be of this nature: the means employed should in the end be none other than the definition of the subject. Science, in the typical example used above, is obtained from knowledge of the proper reason why the triangle has this property; it is knowledge acquired by means of what is absolutely prior to what is known in a scientific way. This implies that what is prior to the property is also first known by us.

But the name 'science', let alone the adjective 'scientific', is not reserved to such knowledge alone. For, although in science proper we cannot acquire knowledge of the unknown except through the mediation of something else already and better known, not everything that is prior in our knowledge is also prior in itself. Hence it can happen that things better known, in the sense of more intelligible in themselves, which might serve us as means of understanding, cannot at once be reached or used, because what we know first is not always what actually comes first.

If we imagine an ignorant savage, setting out unaided to understand the phenomenon of the electric light in this room, it is clear that the knowledge with which he is obliged to begin will not explain very much. He is aware that when you press a switch the light comes on, and when you press it again the light goes off. This property is not of much value where a knowledge of the source and transmission of electric power is what is wanted, but he will simply have to use it for what it is worth until by means of it he can attain properties nearer to the nature of what he is investigating. In the study of the real world we are usually forced to work backwards in this fashion. For example, we know the alternation of day and night before we know the reason for it — a reason which it took some time to discover. As a consequence, the reason that we offer in support of some general statement that is not self-evident, will usually have to be some proposition reached by observation and induction. This proposition becomes a substitute for the definition required by science in the strict sense.

3. Induction of self-evident principles from sense-perception.

It has just been stated that the propositions which, in the study of nature, we must often make do in place of definitions like those available in mathematics, are arrived at by induction. This term induction is another which we must now examine with some care, if we are to understand what St. Thomas means in his preface. By induction, in general, is meant thinking our way from particulars to universals. The main thing to notice in the beginning is that there are two basically different types of induction. One of them passes unnoticed in ordinary life, because it goes on as unceasingly and as unconsciously as breathing. Just as we hardly notice how we have come to be so sure that Socrates has come into the room and is now before our eyes, so we hardly notice how we have come to be so sure that if he or anything is present it cannot in the same regard be absent. But the fact is that our certainty about the most general principles implied in all reasoning, such as 'it is impossible to be and not to be at the time and in the same respect', is the result of induction, of an act of induction so natural that it may pass unobserved. The other kind of induction, which examines all the particular cases within reach and concludes to a general notion or to a general proposition, is familiar to us as the typical procedure of the arts and crafts as well as of experimental science in general.

In comparing these two sorts of induction, it must be noted that they differ, not merely in the frequency or ease with which they are carried on, but more fundamentally in the role assigned to the enumeration of particular instances and in the certitude finally achieved. It may sound surprising, but an induction may yield entire certitude without all instances having been covered (as in the above-mentioned case of 'intuitive induction') and, on the other hand, may cover all instances without yielding a sufficient reason. The first and basic type of induction, whereby the mind moves from sense perception to general notions and self-evident principles, never attempts a complete enumeration. Indeed, a principle like 'it is impossible to be and not to be etc.', or 'any two things which, in the same respect, are like to a third, are in that respect like to one another', could hardly be the result of an examination of all cases of it. In the process of acquiring knowledge, propositions like this one are manifestly dependent on sensation, memory and experience, yet, once we grasp them, we see that they must hold good in all possible instances. In other words, it is characteristic of this first type of induction that the

survey of the particular cases is not given as the reason for its universality and truth. (5)

4. Induction by enumeration.

Since in the kind of induction which we have just referred to, no amount of particular instances is ever offered as the reason for accepting the strictly universal notion or proposition, it can scarcely be called scientific all by itself, but is rather a necessary preliminary to all science. We must now turn our attention to the second type, where the multiplicity and similarity of the particular cases is actually given as the reason for a general statement which is offered as a conclusion. In this kind of reasoning from particular to universal, the enumeration of the cases may be either complete or incomplete. By complete is meant an enumeration which exhausts all possible cases, provided, of course, they are limited in number. Now, even when complete enumeration is possible, such that the property x is shown to be true of every possible instance, the inductive argument may still fail to give a proper, universal reason for its conclusion, although the conclusion may be known with certitude.

An example, using the materials of geometry, will show us what is meant by complete enumeration failing to reach the proper reason for a proposition that is enounced as a conclusion. Suppose one established that 'the sum of the angles of any triangle is two right angles' by way of induction in that the method one chose was to verify the theorem in each of the three kinds of triangle, "first in the equilateral, again in the isosceles, and afterwards in the scalene triangle". (6) Since these three species exhaust the possible kinds of triangle — for a rectilineal three-sided figure either has its three sides equal, two of its sides

(5) Cf. Post. Anal., II, c. 19, 99 b 15. Cf. St. Thomas, ibid., lect. 20 — (On the distinction between sense-perception, memory and experience, see also Metaphysics, I, c. 1, 980 b 20 - 981 a 30. St. Thomas, ibid., lect. 1.) — Of this universality Aristotle says that it is "at rest in the mind" inasmuch as it is then perceived as independent of the particular, variable, instances, although we are dependent upon the sensation of some instances, upon memory and comparison of the instances retained, which results in experience. If we had no such knowledge, no word we use could have any meaning except as vocal sounds such as are produced by the beasts, i.e. signs of a state of passion, as the dog's bark or the lion's roard. For this type of induction, modern logicians still refer to Aristotle, and call it "immediat" or intuitive induction". See, e.g. W.E. Johnson, Logic, Part II, chapt. VIII, Cambridge, 1922, pp. 188 et sqq.; Morris Cohen and Ernest Nagel, An Introduction to Logic and Scientific Method, Routledge and Kegan Paul, chapt. XIV, pp. 273 et sqq.

(6) On whether Aristotle's mention of such a proof (Post. Anal., I, c. 5, 74 a 15-35) refers to a historical development of the theorem, see Heath, op.cit., vol. I, p. 217 et sqq.

alone equal, or its three sides unequal, — the general statement will be certain enough: 'In every kind of triangle, the sum of the angles is two right angles'. Yet the verification of the general statement by enumeration of all the possible kinds of triangle does not provide the commensurately one and universal reason why it is true of each kind. "... Even if one prove of each kind of triangle that it has its angles together equal to two right angles, whether by means of the same or different proofs; still, as long as one treats separately equilateral, scalene, and isosceles, one does not yet know, except sophistically, that triangle has its angles equal to two right angles, nor does one yet know that triangle universally has this property, even if there is no other species of triangle but these. For one does not know that triangle as such has this property, nor even that every triangle has it, except in a numerical sense; nor does one know it according to the species triangle universally, though there be no kind of triangle in which one does not recognize this property". (7)

In the study of nature, too, an induction is judged complete when some general proposition is taken as true merely because it has been verified of each member of an adequate division; as when it is said that "irritability (the power of responding to a stimulus) is the general property of living beings" because it is true of both animals and plants. (8) However, although this may be the reason why we believe the property to be common, it is not a commensurately universal reason. The same criticism could be made of an argument which would show that all mobile beings are bodies because both animate and inanimate things — a clearly adequate division of mobile beings — reveal three spatial dimensions, yet this is far from being the commensurate universal reason why anything that can be in movement must be a body. A genuine demonstration, would have to show that 'to be per se in movement' belongs primarily to body as such, and this is the effect of Aristotle's reasoning in Book VI of the Physics.

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(7) Post. Anal., I, 74 a 25-35. Cf. St. Thomas, ibid., lect. 11-12. — Inasmuch as 'triangle' and other types of plane figure, such as circle, divide the genus 'plane figure', triangle is a species which, with regard to the kinds of triangle that in turn divide triangle into species, has the nature of genus. Figure is called the 'remote genus', triangle 'proximate genus'.

(8) Even this so-called complete induction is only hypothetical, inasmuch as it must assume that the terms of the division have been verified. Such universality was formerly qualified as "ut nunc", i.e. valid in all the cases considered.

More often, however, the inductions used in the study of nature cannot be made complete. We say, for instance, that 'man is mortal'. If this proposition is considered to be general merely because no man has been known to survive, its basis is an induction that is necessarily incomplete. For all practical purposes, the proposition is sound, but it is not based on the reason why man is mortal: that 'no man has been known to survive' is not the natural reason why 'every man is mortal'. If the sun rises tomorrow, it is not because, in all human experience, it has always happened before. (9) The regularities observed in nature (such as the eventual death of every animate thing), so long as we cannot find the reason why they are, will offer by themselves no solution to the problem. The reason why man, as well as any other animate thing, is mortal must be found in what is inseparable from being an animate thing, and therefore from being a man.

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(9) Aristotle's famous hypothesis of a radical difference between celestial and earthly phenomena is a case in point. He assumed that the former were entirely uniform, unaging and unalterable, from which he concluded that there was no contrariety in them, so that the heavenly bodies, such as the sun, were incorruptible. "The mere evidence of the senses is enough to convince us of this, at least with human certainty. For in the whold range of time past, so far as our inherited records reach, no change appears to have taken place either in the whole scheme of the outermost heaven or in any of its proper parts." (De Caelo, I, 3, 270 b 10.) "Nevertheless St. Thomas adds, in his commentary, lect. 7, n. 6 this not necessary, but only probable. For the more a thing is lasting, the more time is required to observe its change; for instance, the change that takes place in a man, over a period of two or three years, is not as readily observed as that which affects a dog, or some other shorter-lived animal. Hence, one could say that, while the heaven is naturally corruptible, it is so long-lasting that the whole space of time which memory can record is not enough to observe its change."

5. <u>The 'universal' of demonstration is not the same as the universal that is merely 'predicable of many'.</u>

In other words, the universal, as understood in strict science or demonstration, of which an example is 'to have its three angles equal to two right angles', must show the following characteristics: a it must be true of all instances that are under it (e.g., of each and every triangle); b its subject must belong to the very definition of the property (e.g., 'to have two angles equal to two right angles' implies triangle as the per se subject of this property from which it follows with necessity); c it is primarily in that of which it is said (i.e. primarily in triangle as such, and not primarily in each one of its species). (10)

To assume that one has demonstrated that the triangle as such has the sum of its angles equal to two right angles by showing it to be true primarily of each one of its kinds, is to be satisfied with the mere appearance of a reason. In fact the statement: 'In every kind of triangle the sum of the angles is two right angles', when it is understood as the result of an induction by complete enumeration, is not a demonstrative conclusion at all, but a mere restatement of something already known, viz. a that any triangle is either <u>e</u>, <u>i</u>, or <u>s</u>; b that <u>e</u>, <u>i</u>, and <u>s</u> each have their angles equal to two right angles.

What we are trying to show is that to establish something by induction as true of a class of things is not to prove anything about the nature of the thing in itself. Such inductions, however exhaustive, will always suffer from this limitation. The reason is that a class as such, is never the same thing as a universal. A class, or collection, is no more than an incidental whole, a grouping which supposes something held in common by many objects, but not necessarily something pertaining to what they are in themselves. If, instead of meaning 'a rectilineal figure contained by three sides', which is one in notion, the term 'triangle' were used to stand primarily and immediately for the <u>class</u> of each and all triangles, 'triangle' could be said of no triangle whatsoever, neither of a kind nor of an instance of a kind. Where 'triangle' is intented to mean a class of things, to say triangle of equilateral, or of <u>this</u> particular one, would mean that 'equilateral' is the class of all triangles, whether equilateral or no. Likewise, if, ignoring the rules of <u>supposition</u>,(11) we interpreted 'man' to

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(10) <u>Post. Anal.</u>, I, cc. 4 & 5, 73 a 20 – 74 b 5. St. Thomas, <u>ibid.</u>, lect. 9-12.

(11) Cf. John of St. Thomas, <u>Cursus Philosophicus</u>, <u>Logica</u>, P. I, lib. II, cc. 10-12; <u>Quaest. Disput.</u>, q. 6 (edit. Reiser, t. I, pp. 29-35; pp. 166-182).

mean primarily and immediately the class 'men', that is, all of the subjective parts of the universal nature 'man', then, to say 'man' of Socrates would mean that he is each and every man: Socrates and all men who are not Socrates, i.e. all who have been, are, shall be, might have been, and even 'all the possible men', who are incompossible. Actually, a collection, as such, like an individual, can be predicated only of itself, viz. in a proposition of identity, such as 'Socrates is Socrates' and 'All Greeks are all Greeks'.

If 'triangle' meant primarily and no more than the <u>class</u> of all triangles, the 'equilateral' could not even be called 'triangle' since this would imply that the class of all triangles is in the same respect both equal and unequal to only part of itself. It would be false to say: 'A rectilineal figure that has its three sides equal is a figure', or that 'it is a rectilineal figure', or 'a rectilineal figure that has three sides'. For all these terms would be no more than symbols that stand for a mere collection.

6. <u>On the use of symbols.</u>

The brief remarks on class, which we found it necessary to make in order to appreciate the limitations of some scientific inductions with regard to either predicable or commensurate universality, can now be used to throw some light on the nature and use of symbols. This is to the point, since several departments of natural science must have resort to symbols as distinguished from names. A mere class is such that the mind demands a special sort of sign for it. Our usual communicative signs for natural objects are words or names. But whenever we can give a name to a given thing, it is because our mind grasps it as one per se. We do not have a name for 'pale flutist', inasmuch as 'to be a flutist' and 'to be pale' are not one thing — although there may be a good reason why <u>this</u> flutist is pale. A simple example may help. When we say, 'Let <u>x</u> stand for all the objects in Mr. Smith's backyard', <u>x</u> is not a name, but an arbitrary symbol assigned to stand for the incidental class or group. Now the mind can surely bring the two together, and their being together may be true enough, as in the proposition 'Oscar, the pale flutist, builds a house', provided <u>this</u> person is a flutist, is pale, and builds a house. But a person is not a flutist because he is a person, nor pale because he is a flutist, nor does he build a house because he is a person or a flutist. Although the proposition is true, it could not express all that as something one per se, and there can be no simple name which signifies 'a pale, building, flutist'. But we could say 'let <u>x</u> stand for such a person'.

The origin of the word 'symbol' may help us to understand how it differs from a name. The Greek word 'symbolon' comes from the verb 'symballein', meaning, literally, 'to throw together': syn with + ballein to throw. This original meaning is retained in the term 'Symbol of Faith', such as 'The Symbol of the Apostles', which means a 'collection of truths held by faith, (12) responding to the particular, contingent needs of the time, as distinguished from an intrinsically ordered presentation of doctrine. Hence the word 'symbol' understood as an extrinsic sign of membership in a collection, such as a uniform, which permit one to identify a person as belonging to the army or navy; and the insignia of office. Symbol, as we use it in the present context, is the proper sign of what has no more than the unity of a collection or incidental whole.

We get closer to the latter meaning in the example 'Let x stand for all the objects in Mr. Smith's backyard'. The point to note here is that the sign stands for a definite collection whose members may be unknown except that all of them are in that person's backyard. Hence, x stands for all but for no one of them in particular, nor does it tell us what any of them are.

Symbols, in a more practical sense, are used in the formal logic of the syllogism, such as M for the middle term, P for the major extreme, and S for the minor extreme. These signs should not be understood as abbreviations of names: they are not succinct ways of writing Subject, Middle, and Predicate. In fact, these particular letters have a distinct drawback inasmuch as they appear to be substitutes for words. We may just as well, and even with advantage, replace them by A, B, C, provided they stand for anything that may be invested with the logical intentions of extreme (A, C) or middle (B) terms. The symbols of formal logic are called 'transcendent terms' because they signify 'omnia et nihil'. B, for instance, would signify anything that can be invested with the logical relation of middle term, yet not any such thing in particular; it stands for whatever may turn up as the middle of a syllogism, such as 'man', 'triangle', or 'impossible'. What they have in common refers to an operation of the mind, whereas in reality they may be as incongruous as 'point', 'sneeze', or 'nothing'.

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(12) St. Thomas, IIa IIae, q. 1, a. 9.

7. Logical and mathematical symbols.

The operational symbols of formal logic have, in their proper context, the greatest generality and indetermination inasmuch as they transcend all categories. Since they refer to whatever may be invested with the relation of a syllogistic term, we might call them 'transcendent variables'. These should not be confused with the symbols of mathematics.

Now ciphers, such as 2, 3, 4,..., may be taken as substitutes for names with a view to calculation; but they are sometimes understood as symbols in the above defined sense — as we shall see in n... of the present chapter. It is the signs of algebra, which are more patently symbols of variables and more similar to the transcendent terms of logic, that we must consider at this juncture. They too are operational. But the algebraic symbol refers to a type of operation characteristic of mathematics, viz. the so-called fundamental calculations: addition, subtraction, multiplication and division. While mathematics exhibits the most rigourous type of syllogizing, its reasoning implies and is dependent upon an operation that in itself is not a reasoning process. Consider the elementary equation $x + 2 = 5$. This equation assumes that $x + 2$ on the one hand, and 5 on the other, are equals, where 2 is the known part of the whole that is 5. Hence the unknown part of 5, viz. x, will be the difference between 5 and 2, viz. $5 - 2$. A.v., the reason why $x = 3$ is that $5 - 2 = 3$. The common principle that lies at the basis of this operation is that the parts of a whole are, together, the same as the whole — materially. Now, the subtraction ($5 - 2 = 3$) is not a process of reasoning; yet, owing to this operation we can reason to the identification of x, the terms of the syllogism being 3 (A), $5 - 2$ (b), and x (C). It is the equality exhibited by $5 - 2 = 3$ that is the proximate reason why $x = 3$. (x)

To assume that the symbols of logic and those of mathematics have the same generality, e.v. that in the equation $y = m + x$, x can have a generality coextensive with B, the middle term, would imply either that the nature of the things

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(x) Alfred North Whitehead, in An Introduction to Mathematics, states this as something that is self evident. "Now the first noticeable fact about arithmetic is that it applies to everything, to tastes and to sounds, to apples and to angels, to the ideas of the mind and to the bones of the body. The nature of the things is perfectly indifferent, of all things it is true that two and two make four. Thus we write down as the leading characteristic of mathematics that it deals with properties and ideas which are applicable to things just because they are things, and apart from any particular feelings, or emotions, or sensations, in any way connected with them. This is what is meant by calling mathematics an abstract science."