plurality of sciences within the first degree of abstraction, the issue becomes highly controversial. The problem is whether the study of nature is specifically one, or only generically one. In its concrete form it reduces itself to the problem of the kind of distinction existing between philosophy of nature and experimental science. Since this question is of considerable importance for our purpose, we must endeavour to give it a rather exact analysis.

Speaking in a general way, we may say that until recent years Thomists recognized no formal distinction between the philosophy of nature and what has come to be known as "science." -- at least no distinction of such a nature as to give rise to two specific sciences. And this is of considerable significance, for if there is anything that the medieval Thomists took pains to do it was to introduce formal distinctions wherever there was any basis for them. This was particularly true in the realm of knowledge.(87) But some modern Thomists, notably M. Maritain, while recognizing the absence of any formal distinction between the philosophy of nature and "science" in the writings of Aristotle and the medieval Thomists, believe that this was a serious error on their

part -- an error due to "intellectual precipitation" and an unwarranted "optimism".(88) They have consequently seen fit to reject this point of Thomistic doctrine, and have gone to great pains to elaborate an epistemological theory which attempts to set off the philosophy of nature and experimental science as two formally distinct sciences.(89) While commending the motive behind this elaboration -- that of attempting to integrate Thomistic philosophy with modern achievements, we feel that it has resulted in a theory that is in conflict with basic Thomistic epistemological principles. We must try to see why this is so, and why these principles must be retained if modern experimental science is to have its true explanation.

In order to set the question in a clearer light, it will be necessary to make several distinctions. In the first place, it is evident that there is a specific difference between philosophy of nature and mathematical physics. For as we have already suggested, mathematical physics does not fall completely under the first degree of abstraction. It is a hybrid science whose formal element is borrowed from the second degree of abstraction. Hence it is formally distinct from science that is of a purely physical character. The whole question at issue is

whether there can exist a plurality of specifically distinct sciences which fall completely within the first degree of abstraction. In the second place, we do not deny that there is a profound epistemological difference between philosophy of nature and experimental science. In fact, we shall lay considerable stress upon this difference in Chapters IV and V. But, it is not a question of a difference between two specifically distinct sciences of nature, in the strict sense in which science signifies universal and necessary judgments. Rather, it is a distinction between a science of nature in the strict sense (philosophy of nature) and a purely dialectical continuation of that science (experimental science). We shall try to make it clear later that experimental science is not science in the strict sense just defined. None of its judgments are universal and necessary; they never go beyond a greater or lesser degree of probability. Only the facts of science have certainty. And we shall see that the greatest of modern scientists and philosophers of science are in agreement on this point. In other words, the reasoning used in experimental science proceeds from hypothetical premises to probable conclusions. It is for this reason that we shall call this type of knowledge

dialectical knowledge. And in the future when we speak of experimental science it must be understood that we are taking the term science in the broad sense in which it signifies purely dialectical knowledge. The ambiguity of the word easily gives rise to confusion, and lest some may suspect that it is merely this ambiguity that is at the basis of the difference between Maritain's position and ours, we shall quote the following lines from Yves Simon, who is recognized as the most authentic interpreter of M. Maritain. In explaining Maritain's philosophy of the sciences he writes:

> Whenever the mind seizes an essence, a ratio entis, albeit in the blind way proper to the perimeetical intellection, a genuinely scientific treatment remains possible. Any universal and necessary form of being, however obscure may be the way it is grasped, constitutes a matter to which the mind can apply the principles of scientific thought, that is, causal and explanatory schemes.(90)

Because of the essentially dialectical character of all experimental science, it is evident that there is no possibility of a plurality of specifically distinct sciences in the strict sense of the word within the first degree of abstraction. But we do not intend to argue from this point of view here. Rather, we have in mind

to approach the problem from an entirely different angle. Our position is that even if experimental science were science in the strict sense of the term it would not be formally distinct from philosophy of nature, but united with it to form one indivisible science of nature. On the other hand, if mathematical physics were science in the strict sense of the term, it would be formally distinct from the science of nature.

We can best settle the issue by first considering it in a positive way before taking up the arguments of M. Maritain and his followers. John of Saint Thomas whose doctrine M. Maritain generally professes to follow, has written a special article to show that a plurality of sciences in the first degree of abstraction is incompatible with basic Thomistic epistemological principles.(91) The clarity of the article is admirable, and we can do no better than to summarize its content. The study of nature covers a broad field; it includes a number of branches which extend to a great variety of things. Yet a close consideration of this study reveals the fact that all of these branches must of necessity fall under one indivisible science. For (prescinding from the difference between dialectical and truly scientific knowledge, which John of

St. Thomas does not consider) the only fundamental difference between these various parts of natural doctrine is the difference between generality and concreteness. This difference cannot constitute a formal distinction between sciences. For, as St. Thomas points out on innumerable occasions(92) every science necessarily begins with generalities and progresses to greater and greater concreteness. We have already indicated the reason for this: the human mind begins with potency and moves on slowly to greater actuality. And on these innumerable occasions St. Thomas makes it very clear that the various branches of natural doctrine do not constitute a variety of sciences but only a difference of greater or lesser concretion. John of St. Thomas wisely points out that if the difference between generality and concretion were sufficient to constitute a plurality of sciences, it would be impossible for a specifically distinct science to exist. For, every science that might be set up would necessarily move from some level of generality to greater concreteness.

Consequently, every science which deals with a certain genus necessarily deals with all the species which fall under that genus. Not only do these species not have

the full liberty of specifically distinct sciences, they do not even have the restricted liberty of a subalternated science, because the difference which they add to the generic study is not accidental and extrinsic, but intrinsic and essential.(93) As we pointed out above, sciences are distinguished by the essentially different principles which they employ, for each science has principles that are proper to it. Each science presses on towards its goal in the light of these proper principles, and consequently as it moves from generality towards greater concretion it cannot suddenly change its principles at a certain point along the way. It is true that from a purely material point of view new principles may be added. In this sense each new natural species that the student of nature discovers in experience becomes a new scientific principle for him and the source of new truths. But it is obvious that in this context we are taking scientific principles from the formal point of view which is determined by the modus definiendi that is characteristic of them. In this sense, the principles of a science cannot change. No matter how many new species the student of nature may discover they must all be defined in terms of sensible matter and considered from the point of view of

the ratio mobilitatis. It is evident that if the advent of new principles from the material point of view were sufficient to give origin to new sciences, there would be as many sciences as there are natural elements or species.

Just three things can happen to a science as it moves from generality to greater concretion. First, it may retain its character of strict science all the way, and then no profound epistemological change takes place at any point. This is what happens in the case of geometry, which begins with axioms and postulates of great generality, and which in pursuing its ambition to derive all the implications latent in these axioms and postulates, remains a strict science throughout. Secondly, it may at a certain point lose its character as a strict science and issue into dialectical knowledge. In this case the dialectical knowledge is a necessary continuation of the science as it moves towards concretion. It uses the same principles, but not in such a way as to arrive at strict demonstrations. Obviously this does not give rise to a plurality of sciences. Thirdly, it may call in the help of an outside science in such a way that the two constitute a scientia media. In this last case we

have the only way in which other principles besides the ones that science started out with can be introduced. These three cases are exhaustive. We do not see how any other possibility can be adduced. Let us apply these general considerations to our specific problem of the study of nature.

This study begins with the consideration of mobile being in its broadest generalities: what is motion in general, what are the constituents of all mobile beings, etc. These generalities form the subject matter of the eight books of the Physics. From this point the study moves gradually towards greater concretion, and the other natural treatises are devoted to following out this movement. We do not see how at any point new principles can be suddenly introduced to transform the science into a different science, unless they be brought in ab extrinseco. But if they are brought in ab extrinseco, they necessarily give rise to an intermediary science. This is what actually happens in the study of nature when mathematics is applied. But in this case we have a hybrid science composed of elements from two degrees of abstraction; we do not have a plurality of sciences in the first degree of abstraction.

It is true that as the study of nature progresses it eventually issues into a purely dialectical type of knowledge. But this does not give us a new science. If that dialectical knowledge could be suddenly transformed into strictly scientific knowledge it would merely constitute a continuation of the one science of nature in its movement towards concretion.

The obvious objection at this point is: what about mathematics in which you have two specifically distinct sciences within the same degree of abstraction. And the answer is not difficult to find: There is no science of quantity as such, as there is a science of mobile being as such. In other words a general science of mathematics does not exist, nor can it exist. If it did, geometry and arithmetic would not be specifically distinct, for as we pointed out above, the science which deals with the genus deals also with the species that fall under it. In other words, mathematics is not the study of quantity from the point of view of its essence; nor are geometry and arithmetic studies of continuous and discrete quantity from the point of view of their essence. The study of quantity and its species from the point of view of essence is distinctly a meta-

physical consideration. For it pertains to metaphysics to explore the nature of all the categories from the point of view of their essence, i.e. in so far as they are principles of being. This includes even the categories that involve matter. Nor is this a contradiction of what was said above about metaphysics prescinding from all matter, for metaphysics considers and defines these categories not from the point of view of their materiality but in so far as they are principles of being. This explains why St. Thomas can say: "De quolibet enim ente inquantum est ens, proprium est metaphysici considerare."(94) And later in the same lectio he writes:

> Licet ad considerationem primae philosophiae pertineant ea quae sunt separata secundum esse et rationem a materia et motu, non tamen solum ea; sed etiam de sensibilibus, inquantum sunt entia, philosophus perscrutatur.(95)

And so he concludes: "Geometria accipit quid est magnitudo a philosopho primo."(96)

The case of the study of nature is entirely different from that of mathematics. And it will sharpen the issue to present it in the form of a disjunction. Either there is a specific science of mobile being as such, or there is not. If there is not a special science, then

under what science does the study of mobile being fall? Certainly not metaphysics, for mobile being is not a category or a principle of being, as quantity is. On the other hand, if there is a science of mobile being as such, then everything that falls under the formality of mobility from the broadest generality to the ultimate concretion will pertain to the same science. One cannot begin the study of mobile being in its generalities and then somewhere along the road to concretion suddenly shift to other principles. A particular, concrete type of movement is a contraction of movement in general. But continuous quantity is not a contraction of discrete quantity or vice versa. In this case there is something entirely new.

This clarification of the difference between mathematics and the study of nature will help to bring out the ambiguity in the following statement of Maritain:

> .. la différence entre la philosophie de la nature et les sciences des phénomènes, soit empiriométriques soit empirioschématiques, apparaît comme beaucoup plus accusée que la différence entre l'arithmétique et la géométrie, lesquelles étaient pour les scolastiques deux sciences spécifiquement distinctes.(97)

Several distinctions are necessary here. There is a greater distinction between the philosophy of nature and experimental science in the sense that the former is strictly scientific knowledge, while the latter is only dialectical; whereas in both geometry and arithmetic there is strictly scientific knowledge. On the other hand, however, there is a greater difference between geometry and arithmetic in the sense that they are two formally distinct sciences, each possessing its own proper principles. Of course in the case of the sciences which Maritain calls empiriometric there is a deeper dichotomoy separating them from philosophy of nature because of the fact that they constitute a hybrid science.

As a confirmation of his position, Maritain writes: "Jean de Saint-Thomas distingue ainsi la philosophie naturelle et la médecine."(98) It seems almost incredible that this agrument should be adduced, especially since the word "ainsi" refers directly to the lines immediately preceding wherein Maritain explains his distinction between philosophy and experimental science. For John of Saint Thomas, while admitting a distinction between medicine and philosophy of nature (which in his terminology included the entire study of mobile being)

explicitly and in so many words rejects this distinction as an argument for a plurality of sciences of mobile being. And the reason for this rejection ultimately boils down to this that medicine and the study of nature are formally distinct because medicine is not a speculative science like the study of nature but a practical science. For while they both have the same material object: body, they have a distinct formal object in that natural doctrine considers bodies as mobile and medicine considers them as curable. Even though the act of curing takes place by means of motion, medicine does not consider its object in terms of the formality of motion, but in terms of curability.

St. Thomas brings this point out with great precision in his Commentary on the De Trinitate:

> Quamvis enim corpus sanabile sit corpus naturale, non tamen est subjectum medicinae, prout est sanabile a natura, sed prout est sanabile per artem... Et sic relinquitur quod physica secundum se, et secundum omnes partes eius est speculativa, quamvis aliquae operativae subalternentur ei. (99)

It is precisely because medicine is a practical science that John of St. Thomas writes " magis concretive procedit magisque ad singularia et praxim accedit.(100) And while

experimental science actually proceeds in a more concrete way than philosophy of nature, and comes closer to singulars, no parity can be established between it and medicine, because even though an experimental science progresses it takes on more and more the character of practical knowledge, as we shall see, it remains essentially a speculative science. It is difficult to see how a distinction between a speculative and a practical science can afford any argument to prove the existence of a plurality of speculative sciences in the first degree of abstraction.

But it is time now to consider briefly the positive arguments of M. Maritain.(101) The basis of his distinction between philosophy of nature and experimental science seems to consist in this: The object of the study of nature is sensible being -- ens sensibile.(102) This object presents a dualistic or bipolar character, and it is this dualism or bipolarity which gives rise to two vastly diverse ways of studying nature. For it is possible to study sensible being in such a way that the emphasis is placed upon "being", and when this is done you have philosophy of nature. It is likewise possible to study sensible being in such a way that the emphasis is put upon "sensible", and then you are in the realm of experimental science. Out of this difference of accentuation arise

two diverse conceptual schemes, two diverse modes of definition. The philosopher of nature defines his concepts in terms of intelligible being, the experimental scientist in terms of sense phenomena. The one employs dianoetical intellection, which consists in penetrating to the essence of things. The other uses perinoetical intellection which consists in grasping the essence only in a blind and remote way in the phenomenal regularities themselves. The one resolves its concepts in an ascending analysis which goes up to intelligible being. The other resolves its concepts in a descending analysis which goes down to the sensible, the phenomenal. Hence the one moves from the visible to the invisible. The other from the visible to the visible.

Professor Simon, with his usual clarity, has attempted to give an exact and concrete explanation of Maritain's ascending and descending analysis:

> Let us try a rigorous ascertainment of the meaning of a word found in both philosophical and in positive contexts. The example chosen may be very simple. To the question what does the word 'man mean' mean? the answer will be 'rational animal'; now, none of the elements of this definition presents a character of irreducible clarity. Take one of them, for instance, animal. What does the word mean? A correct definition would be: 'a living body endowed with sense knowledge',

and these are so many terms which badly need clarification. Take one of them, for instance, 'living.' I would say that a body is a living one when it moves itself, when it is the active origin of its own development. If we go any step further, we go beyond the limits of physical thought. In order to render the idea of life clearer, we would have to define it as self-actuation. The concept of self-actuation does not imply any reference to the proper principles of corruptible and observable things: it is a metaphysical concept. Its elements are identity and causality. Identity is the first property of being. Causality can be analysed into potency and act. Identity, potency and act are so many concepts directly reducible to that of being, which is, in an absolute sense, the first and most intelligible of all concepts. We have reached the ultimate term of the analysis, the notion which neither needs to be nor can be defined and which does not admit of any beyond ....
For the zoologist, man is a mammal of the order of Primates. How would he define such a term as mammal? A vertebrate characterized by the presence of special glands secreting a liquid called milk. How is milk defined? In terms of color, taste, average density, biological function, chemical components, etc.
Here the ultimate and undefinable element is some sense datum; it is the object of an intuition for which no logical construction can be substituted and upon which all the logical constructions of the science of nature finally rest.(103)

We fail to find in all this the slightest basis for a duality of sciences in the study of nature. There are two main differences between the definition of the philosopher of nature and that of the experimental scientist.(104) Both of them, far from constituting a

a specific distinction between sciences, absolutely exclude the possibility of such a distinction. In the first place, the definition of the philosopher is strictly scientific, whereas that of the zoologist is purely dialectical. Obviously, if the definitions of experimental science are purely dialectical, it cannot be a specifically distinct science, for the simple reason that it isn't a science. The second difference between the two definitions is one of generality and concreteness. Whereas the philosopher of nature deals in broad generalities the experimental scientist is far advanced along the road to concretion. In this sense the former is far less immersed in the directly observable than the latter. If this is what M. Maritain means by saying that the one moves from the visible to the invisible, while the other goes from visible to the visible, he is correct; but besides being an extremely ambiguous and confusing way of explaining the situation, it provides no foundation for a specific distinction between sciences.

Because the experimental scientist is deeply immersed in concrete materiality, it is only natural that he will clarify his definitions in terms of concrete,

material observable things. If we asked St. Thomas to clarify his material definition of a house: "a structure made of stones, cement, and wood" (105) he would undoubtedly do so in terms of material observable things.

It should now be fairly clear that the difference in materiality between philosophy of nature and experimental science upon which M. Maritain seems to base his specific distinction is not one that derives from formal abstraction which alone can specify the sciences, but merely from total abstraction, since it is a question of a difference between generality and concreteness. This difference, far from constituting a duality of sciences, absolutely excludes the possibility of such a duality, for we have already seen that the more particular must pertain to the same science as the more general.

But it may be objected: if the main difference between the definition of the philosopher and that of the experimental scientist consists in a question of generality and concreteness, why should it not be possible for the experimental scientist to clarify his definition by retreating into higher levels of generality and thus rejoin the philosopher, and why should it not be possible for the

philosopher to push ahead into concretion and rejoin the experimental scientist. Our answer is that not only is such a thing possible, but in a certain sense absolutely necessary. Let us try to see why this is so.

In the first place, it must be noted that the ascending analysis attributed to the philosopher of nature is nothing but an ascent of the Porphyrian tree, a retreat into potentiality, that is to say into generalities that become increasingly more vague and more empty. The philosopher of nature may, indeed, make this ascent, provided he does so in terms of mobility. But it is important for him to realize that while this ascent is leading him in the direction of that which more knowable quoad nos, it is leading him farther and farther away from that which is more knowable in se. In other words, by the very fact that he is practicing total abstraction he is achieving greater intelligibility quoad nos only at the expense of sacrificing intelligibility in se. Now philosophy does not consist merely in giving terms that are more knowable for us, but in manifesting the natures of things as perfectly as possible. It consists in getting at what is more knowable in se and not merely what is more knowable quoad nos. Definitions are

supposed to manifest things to us and this manifestation does not come from a retreat into notions that become increasingly more vague and empty. The only way in which a philosopher can truly philosophize is, not by retreating backward into potentiality, but by pressing forward into fuller actuality. In no other way can he succeed in bringing to light the proper natures of things. That is why, as we noted above, St. Thomas in all of his preamia to the natural works of Aristotle, keeps insisting that the philosopher of nature must constantly move forward into fuller concretion.

With these remarks in mind let us return to the passage quoted above from Mr. Simon. In the first place, it must be noted that Mr. Simon has chosen his examples with care, for apart from the fact (over which we shall not linger) that he has made the philosopher explain the generic part of his definition, and the zoologist the specific part of his definition, he has, in selecting the example of rational animal, chosen a very privileged case. As he himself suggests (106) man is the only natural species for which it is possible to give a strictly scientific definition. From this point of view it provides a kind of terminus for the natural philosopher's quest to get

at the proper natures of things. This is far from saying, however, that his movement towards concretion has come to an end in so far as the nature of man is concerned. For both "animal" and "rational" are rather vague notions which must be explored and concretized. Having determined that man is a rational animal, the student of nature is forced to attempt to find out, for example, what precise structure of body is proper to rational animality. And this attempt will very speedily bring him to the definition given by the zoologist. But in order to bring out the issue clearly let us use another example.

Let us ask the philosopher of nature to tell us what a horse is. And while we await the answer let us recall a remark of Professor Simon: philosophy of nature "does not reach its end until it is able to answer the question 'What is the thing under consideration?'" (107) Where will the philosopher turn to tell us what a horse is? Will he turn upwards in his ascending analysis? If so, we are justified in becoming impatient and calling him back, for he is not telling us what a horse is; he is merely telling us what all animals in general are. Is it not evident that in order to answer the question "what is a horse" he must move in exactly the opposite direction?

It is useless to retreat into logical potentiality; he must push forward along the road to concretion into greater actuality. It may be that he will never be able to give us a perfect answer, but if he is true to his science that will not keep him from an endless striving to get at least a partial answer. M. Maritain seems to admit the necessity of this movement towards concretion in every science, for he writes: "Toute science allant d'ailleurs dans cet ordre vers la plus grande détermination, exigeant que l'objet soit serré, pour ainsi dire, dans une notion propre, et non pas enveloppé dans une notion commune plus ou moins flottante." (108)

We know what reply this objection would receive: (109)

the philosopher of nature must not attempt to answer such questions. He must practice the spirit of poverty; he must not be guilty of the exaggerated optimism and philosophical imperialism of the ancient Thomists. He must leave questions of that kind to the experimental scientist who with his special science completes the philosopher's study of nature. And why? Because philosophy of nature is wisdom within the order of physical reality. Or "toute sagesse est magnanime, ne s'embarrasse pas du détail matériel

des choses, pauvre donc en ce sens, et libre, comme les vrais magnanimes; et cette sagesse-là est <u>obligée</u> à la pauvreté; elle doit se résigner à connaître, elle doit s'honorer de connaître le réel par des moyens pauvres, sans prétendre épuiser le détail des phénomènes, compter les cailloux du torrent." (110) We fail to see the force of this argument. Strange magnanimity this, the renunciation of the knowledge of things in their proper specificity. Far from being a property of wisdom, such magnanimity is directly opposed to its true nature. And if human wisdom cannot succeed in reaching things in their proper specificity, it is not because it is wisdom but because it is human and therefore extremely imperfect. But precisely because it is wisdom it must ever strive towards the knowledge of specific natures.

These last lines of Maritain are rather hard on St. Thomas. For let us recall that he has already told us that the doctrine of the ancient Thomists (St.Thomas included) which held that the philosopher of nature should push forward into concretion was a grave error. If then the reason why the philosopher of nature must abstain from concrete questionsis that he is obliged to do so by the very fact that philosophy of nature is wisdom, the con-

clusion is inevitable: St. Thomas was unaware of the true nature of wisdom. We prefer to believe that his ideas on the nature of wisdom were more exact than those of M. Maritain.

We admit that there is a sense in which it is true to say that the philosopher of nature is brought up short before such concrete questions. But the reason is not that he runs into another science, but that he runs out of science. But there is no reason why he should not prolong his study of nature dialectically even when he is unable to do so scientifically. And when this is done the philosopher and the zoologist inevitably meet.

If there were any valid reason why the philosopher of nature should remain in his generalities and feel satisfied with his ascending analyses, it would have to be because in this way he could derive the greatest illumination concerning nature and obtain the deepest insights into physical reality. But this would necessarily mean that the generalities would contain all their inferiors actually and distinctly, and that what is more knowable for us would be at the same time more knowable secundum se. Not a few modern scholastics, with their false air of profundity in dealing with these

vague generalities which considered from the point of view of the proper natures of things that constitute the goal of the science of nature, provide the most empty and superficial knowledge it is possible to have of the cosmos, seem to hold such a view, at least implicitly. And to hold a view of this kind is to fall into the error of the Platonists who wanted to reach the terminus of science merely by division. Plato's attempt to arrive at the notion of angler through a mere process of division beginning with the general notion of art is well known. (111) In the last analysis this kind of philosophy of nature is nothing but Hegelianism. Karl Marx's explanation of Hegel on this point is extremely illuminating:

> Quand, à partir des pommes, des poires, des fraises, des amandes réelles, je forme la représentation générale: fruit, quand je vais plus loin et que je me figure que ma représentation abstraite: le Fruit, obtenue à partir des fruits réels, est une essence qui existe en dehors de moi, est même l'essence véritable de la poire, de la pomme, je déclare -- en termes spéculatifs -- que le Fruit est la "substance" de la poire, de la pomme, de l'amande, etc. Je dis donc que l'essentiel de la poire, de la pomme ce n'est pas d'être pomme ou poire. L'essentiel de ces choses n'est pas leur être réel, tombant sous les sens, mais l'essence de ma représentation: le Fruit. Je déclare donc que la pomme, la poire, l'amande, etc. sont de simples modes -- mode -- du Fruit. Mon entendement fini, soutenu par les sens, distingue sans doute une pomme d'une poire, et une poire d'une amande, mais ma

Raison spéculative déclare que cette distinction sensible est inessentielle et indifférente. Elle voit dans la pomme la même chose que dans la poire, et dans la poire la même chose que dans l'amande, à savoir le Fruit. Les fruits réels particuliers ne sont plus que des apparences du fruit, dont la véritable essence est la substance, le fruit ... Le Fruit n'est pas une essence sans vie, sans caractères distinctifs, sans mouvement, mais une essence vivante, distincte en soi, en mouvement. Le caractère distinct des fruits profanes ne relève aucunement de mon entendement sensible, mais du Fruit lui-même, de la Raison spéculative. Les fruits profanes distincts sont des manifestations vivantes, distinctes, du Fruit unique, ils sont des cristallisations qu'élabore le Fruit lui-même. Par exemple, dans la pomme, le Fruit se donne une apparence de pomme, dans la poire une apparence de poire. On ne doit donc plus dire, comme du point de vue de la substance: la poire est le fruit, la pomme est le fruit; l'amande est le fruit, mais bien plutôt: le Fruit se présente comme pomme, comme poire, comme amande, et les différences qui séparent les unes des autres la pomme, la poire, l'amande sont les différences mêmes du Fruit et elles font des fruits particuliers des chaînons différents dans le processus vital du fruit. Le Fruit n'est donc plus une unité sans contenu, sans distinctions, il est l'unité en tant que généralité, que "totalité" des Fruits, qui forment une succession, le fruit se présente comme une existence plus développée, plus complètement exprimée, jusqu'à ce qu'il soit enfin "le résumé" de tous les fruits en même temps que leur unité vivante.(112)

We have quoted this long passage because it characterizes so well the attitude of many modern scholastics who seem to look upon the general as the very substance of things and the specific as a mere phenomenal mode which is of little interest for the philosopher who

must concentrate his attention upon the profound essences of things. We believe that the doctrine of Maritain tends to encourage this attitude. It does so in many ways: by insisting upon ascending analyses and neglecting the movement towards concretion; by describing experimental science as something which merely deals with phenomenal details, without explaining that it is precisely through experimental science that we are constantly carried closer and closer to the proper natures of things which constitute the goal of the whole study of nature, closer and closer to the most profound knowledge that it is possible to have of the cosmos -- to the kind of knowledge that God has of nature; etc. Maritain does, indeed, point out the poorness of the knowledge provided by philosophy of nature, but he does so in such a way as to make it appear that the riches which it renounces are hardly worth having. He compares the knowledge that experimental science gives with counting the stones in a stream. St Thomas had already taken care of this counting of stones when in explaining the opening lines of Aristotle's Physics where we are told that in the study of nature the mind must move in the direction of concretion by progressing from universals to singulars, he wrote:

> Hic autem singularia dicit non ipsa individua, sed species; quae sunt notiores secundum naturam, utpote perfectiores existentes et distinctam cognitionem habentes; genera vero sunt prius nota quoad nos, utpote habentia cognitionem in potentia et confusam.(115)

The same point is brought out by Saint Thomas in the Prooemium of his Commentary on the Libri Meteorologicorum:

> Unde manifestum est quod complementum scientiae requirit quod non sistatur in communibus, sed procedatur usque ad species: individua enim non cadunt sub consideratione artis; non enim eorum est intellectus, sed sensus.

But there is even a greater danger in Maritain's doctrine than the one just mentioned. We believe that it tends to lead to a confusion between philosophy of nature and metaphysics, in spite of Maritain's explicit efforts to keep the two distinct.(114) The difficulty here arises from the initial error of seeing in the object mobile being a dual or bipolar character which gives rise to two formalities. Earlier in this chapter we have rejected this error and pointed out that the great Thomists have traditionally insisted that the dualism in the expression "mobile being" is purely verbal, that it signifies one indivisible formality. Having created his two formalities, Maritain goes on to say that the object of philosophy of nature is mobile being or sensible being considered

precisely in so far as it is being. Now, as we saw above, St. Thomas in his Commentary on the Sixth Book of the Metaphysics repeatedly insists upon the fact that no other science can deal with any particular type of being precisely in so far as it is being except metaphysics. And he says explicitly that this is true of sensible being: "etiam de sensibilibus, inquantum sunt entia, Philosophus perscrutatur."(115) And the difficulty is only augmented when one constantly runs across such misleading statements as the following: " ... il faut dire que l'objet propre de la philosophie de la nature ...n'est constitué que par le transcendantal être en tant que déterminé et particularisé au monde corporel, mobile et sensible."(116) "En réalité elle (la philosophie de la nature) considère les choses corporelles et mobiles au point de vue du transcendantal être imbibé en elles."(117)

And even if philosophy of nature could in this position save itself from identification with metaphysics, it would at best have the appearance of an intermediary science subalternated to metaphysics. We do not accuse M. Maritain of holding this view, but it is interesting to note that more than one author who have followed in his wake have explicitly arrived at this conclusion.(118)

and a greater epistemological perversion could hardly be imagined. (119)

But let us return to the definitions of the philosopher and the zoologist. From the foregoing it should now be clear why the philosopher of nature must move forward towards concretion and join the zoologist. But the question now suggests itself: can this meeting be brought about by having the zoologist move backwards as well as by having the philosopher move forwards? Once again the answer must be in the affirmative. If we ask a zoologist what a vertebrate is, he will probably answer: an animal with a spinal column. By seeking for an explanation of "animal" we can make the same ascent in the Porphyrian tree made by the philosopher. But one will immediately be tempted to object: granted that such an ascent is possible, why is it that it is never made by the experimental scientist? Why is it that, as Simon points out, (120) such a way of explaining terms would ordinarily move a zoologist to laughter? The reasons are not far to seek. Modern experimental scientists have chosen to ignore completely the higher levels of generality in the science of nature, and to begin their study with purely experimental propositions. Experimental propositions

are concrete and dialectical. The reason why the subject and the predicate are united is concrete experience alone. Hence it is only natural that when asked to explain the terms in such definitions they should turn to concrete experience. While it is not necessary for them to know philosophy of nature in order to become expert experimental scientists, such a knowledge would enable them to understand the meaning of their science and the proper significance of the terms and propositions they employ. A zoologist with a knowledge of philosophy of nature would have no difficulty in making an ascending analysis of his terms and thus rejoin the definition of the philosopher of nature. And in connection with the question why the zoologist ordinarily makes a descending rather than an ascending analysis perhaps this last remark should be made: experimental scientists have understood far better than scholastic philosophers of nature that the proper movement of the study of nature is forward into actuality, rather than backward into potentiality.

Before leaving this criticism of the doctrine of Maritain, we should like to put it to a final test. We are told that dianoetical intellection is characteristic

of the science of nature which employs ascending analyses, while perinoetical intellection is proper to the science which employs descending analyses. Let us take the example of a definition of man in terms of the tongue and the hands. Now while most definitions in terms of the concrete structure of the body are purely synthetic and hence dialectical, as in the case of the definition of man as a mammal, it seems that the definition in terms of the tongue and the hands is analytic, for there is a necessary connection between rational animality (which implies an animal that possesses both a speculative and a practical intellect) and these two organs. If then one were to attempt to resolve the concepts contained in this type of definition in which direction would he turn? Would he not be led to explain himself in terms of concrete, material observable things? We are consequently faced with this question: what kind of intellection do we find in the proposition just mentioned? Is it dianoetical? If so, why do we have a descending rather than an ascending analysis? Is it perinoetical? If so, how explain that we have an analytic proposition, for in all analytic propositions the essence is opened up and does not remain covered over.

5. Natural Doctrine and Practical Knowledge

At this point it is necessary to introduce a problem which arises out of a text of Aristotle. The solution of this problem will serve to clarify our conception of the nature of natural doctrine and of its relations to the other branches of knowledge. The text we have in mind is found in the first chapter of the first book of the De Partibus Animalium. It is a text to which comparatively little attention has been given by the commentators of Aristotle; yet it is pregnant with profound implications. In spite of the fact that in all the other passages in his writings where he considers the nature of natural doctrine he classes it among the speculative sciences, in this particular text he seems to set it in opposition to the speculative sciences.

> The causes concerned in the generation of the works of nature are, as we see, more than one. There is the final cause and there is the motor cause. Now we must decide which of these two causes comes first, which second. Plainly, however, that cause is the first which we call the final one. For this is the Reason, and the Reason forms the starting-point, alike in the works of art and in the works of nature. For consider how the physician or how the builder sets about his work. He starts by forming for himself a definite picture, in the one case perceptible

to the mind, in the other to sense, of his end -- the physician of health, the builder of a house -- and this he holds forward as the reason and explanation of each subsequent step that he takes, and of his acting in this or that way as the case may be. Now in the works of nature the good end and the final cause is still more dominant than in works of art such as these, nor is necessity a factor with the same significance in them all; though almost all writers, while they try to refer their origin to this cause, do so without distinguishing the various senses in which the term necessity is used. For there is absolute necessity manifested in eternal phenomena; and there is hypothetical necessity, manifested in everything that is generated by nature as in everything that is produced by art, be it a house or what it may. For if a house or other such final object is to be realised, it is necessary that such and such material shall exist; and it is necessary that first this and then that shall be produced, and first this and then that set in motion, and so on in continuous succession, until the end and final result is reached, for the sake of which each prior thing is produced and exists. As with these productions of art, so also is it with the productions of nature. The mode of necessity, however, and the mode of ratiocination are different in natural science from what they are in the oretical sciences; of which we have spoken elsewhere. For in the latter the starting-point is that which is; in the former that which is to be. For it is that which is yet to be -- health, let us say, or a man -- that,owing to its being of such and such characters, necessitates the pre-existence or previous production of this and that antecedent; and not this or that antecedent which, because it exists or has been generated, makes it necessary that health or a man is in, or shall come into, existence. (121)

We have italicized the lines in this passage to which we wish to call particular attention. There can be no doubt that in these lines physics is distinguished from speculative science. And after all that was said above about the place it occupies in the first degree of formal abstraction which distinguishes the speculative sciences, this presents us with a problem that must be solved. Two possible interpretations of the passage just cited suggest themselves: natural doctrine is distinguished from the speculative sciences either because it is essentially a practical science, and consequently not speculative at all, or because though essentially a speculative science, it has some characteristics in common with practical knowledge and in some measure falls short of the perfection of speculative knowledge. After all that has been said thus far it must be evident that only the second interpretation is acceptable. Natural doctrine must be essentially a speculative science, because in it knowledge is sought for its own sake.

As our analysis proceeds we hope to make it clear in how many ways natural doctrine comes close to practical knowledge, and we do not wish to anticipate these developments here. Yet it will be helpful,perhaps,

to set down in skeletal fashion some of the salient features of the striking resemblance between the study of nature and practical science.

In the passage cited above, Aristotle suggests the basic reason for this resemblance. Like all the characteristics of the study of nature, this resemblance derives from the fact that the object of this study is mobile being. Now mobile being means not only being that is, but being that becomes. And the study which deals with such a being precisely in terms of its mobility will deal with it not merely in its being but in its coming to be. And it is because all natural things are mobile beings that we find in nature something closely akin to what is found in art and prudence; we find a becoming, a generation, a prod ction, a movement towards an end. And whenever there is an end, it always acts as principle, as Aristotle points out in the text just cited: "in the former (the starting point is) that which is to be. While this characteristic of natural beings establishes a similarity between them and the things of art and prudence, it at the same time distinguishes them from mathematical and metaphysical things. For, as we have seen, the objects of both

mathematics and metaphysics are immobile. To this it might be objected that there is a kind of production in metaphysical beings, since angels produce a succession of actions. But b ecause it is merely a question of actions, this production touches only the accidental order. In natural things, on the contrary, it touches the substantial order itself. Because of the matter and privation in the essence of these beings, there is in them an intrinsic plasticity that makes them substantially formable. They are not merely called into existence; their generation is the terminus of a lengthy process of composition and formation in which nature proceeds like art. In mathematics there is no formability. It is true that there is a kind of construction in mathematical science, but this does not involve movement or production in the true sense of the word. And that is why the only kind of art that is possible in mathematics is speculative art.

Now we are in a position to understand the profound distinction which Aristotle introduces here between the object of natural doctrine and the objects of the other speculative sciences. Since the objects of the other speculative sciences do not become, they

simply are. That is why Aristotle says that these sciences have to do merely with that which is. But mobile being becomes. And since all becoming, all movement gets its whole specification and determination from the terminus, the science which studies such a being will be engaged primarily not with that which is, but with that which will be, that is to say, the end, which is first in intention and last in execution. And this end is a good, and moves as a good. All this reveals the fundamental role that finality plays in the study of nature as in all practical science and explains why Aristotle insists so strongly upon finality in nature in the second book of the Physics.

It is because of this dependence upon the end that existence plays a part in the study of nature that it does not play in mathematics or metaphysics which deal with essences -- a part that is similar to the part it plays in practical science. For in the notion of end there are two aspects: end in the order of intention, i.e. end as a cause; and end in the order of execution, i.e. end as an effect. Now it is precisely existence which separates these two. And it is because of movement, becoming, that the two terms are united. The study of nature has to consider what goes on between these two terms. That is why

existence is so important for it. That is why it is not merely concerned with the quod quid est as mathematics and metaphysics are. And it is to be noted that the end involved in nature is the very form of natural things, and consequently it is due to becoming that the very object of the study of nature is constituted.

All this serves to bring out the striking resemblance between the study of nature and practical knowledge. But it also makes it clear that from this point of view natural doctrine can be called practical knowledge only by extrinsic denomination, that is to say, because of the nature of the things with which it deals.

What we have been saying enables us to understand the particular type of necessity that is found in the sciences of nature. Since, as we have pointed out, all science deals with necessity, the nature of the science is intrinsically determined by the kind of necessity that is proper to it. Now there are two kinds of necessity: absolute and hypothetical. As Aristotle explains at the end of the second book of the Physics,(122) things which have their necessity from a formal, material or efficient cause enjoy absolute

necessity. On the other hand, the necessity which derives from the final cause is only hypothetical. And hypothetical necessity consists in this: if a certain end is to be achieved, then such and such means are necessary. But it does not follow that given these means, the end will necessarily be achieved. For example, we may say that if a certain type of organism is to be generated, then the conjunction of a sperm and an ovum is necessary. But it does not follow from the fact of this conjunction that the organism will necessarily be, for the end may fail to be achieved for some reason or other.

In order to understand this point clearly we must have recourse to a distinction made by Aristotle in the second book of the Physics.(123) The end that is found in natural things may be considered in two ways. It may first of all be considered as a principle of reasoning, and then it is taken as the cause from which we may demonstrate all the things that are necessary for the end to be realized. In this sense we can reason from the end to the means that are necessary for the end. But it may also be taken as a principle of action, that is to say as the cause moving the agent. In this sense it is impossible for demonstration to actually reach the end,

that is to say, we cannot reason from the fact that the means necessary for an end are given that the end is going to be realized.

In all of the speculative sciences besides the study of nature absolute necessity is found, but in natural doctrine there is only hypothetical necessity. Here we have another point in common with the realm of the practical. And so Aristotle concludes: "For there is absolute necessity, manifested in eternal phenomena; and there is hypothetical necessity, manifested in everything that is generated by nature as in everything that is produced by art, be it a house, or what it may."(124) Hence in natural science no true demonstration from prior causes is possible, for, from the point of view of prior causes, whatever happens, happens at best only for the most part -- ut in pluribus.(125)

Nature may in fact be characterized by what happens for the most part. And it is this that St. Thomas has in mind when in a text already quoted(126) he points out that the science of nature has a "modus infirmior demonstrandi" because "multae demonstrationes sumuntur ex his quae non semper insunt, sed frequenter."

This distinguishes it from the other speculative sciences whose demonstrations enjoy a greater necessity. At the same time it reveals the close similarity with practical knowledge, for as Aquinas points out in the same lectio, in the moral sciences the "principia sumuntur ex his quae sunt ut in pluribus."(127)

It is evident, then, that in natural science demonstration cannot arrive at the ipsum esse finis. For example, in the evolution of the cosmos, at no point was it possible to demonstrate with absolute necessity the future existence of any particular natural species -- (128 even though once the existence of a certain species is given in nature it can be the principle of what had to be in order for it to exist. In other words, natural things are not knowable except in the order of existence; that is to say, we cannot know them except by knowing them as existing. This creates a great difference between the science of nature and the other speculative sciences. We stand before the universe as before a work of art in the process of being made. We might have a general notion of what is to come about, but as long as we have no full share in the idea of the artist, we do not know just what is to come about or exactly how. Like practical

knowledge, therefore, the study of nature has a close and necessary relation with the existential order, and consequently with experience. This point will be developed at considerable length in Chapter IV, and in connection with it we shall discover another closely related reason why physics is associated with practical knowledge: it has to do with objects that are formed by divine art. This is not true in the same sense of metaphysics, for angels are not formed in the line of essence. In mathematics everything is analytical.

Besides being about things that are brought into existence by composition, natural doctrine must itself engage in composition. This is true not only in the construction of theories, but already in the gathering of the various subjects considered. The study of nature must be built up out of bits garnered from experience. And closely connected with this is another point of similarity with practical knowledge, namely its intimate relation with singulars. The student of nature cannot deal purely with universals. In fact, as he pursues his research in the direction of fuller concretion, it soon becomes impossible for him to rise successfully above the realm of singulars to true universality, and he is obliged to have

recourse to a kind of artificial and hypothetical construct that is fashioned by the mind. And in connection with the relation between natural doctrine and singulars it is worth while noting that in nature generation is always in the singular. In mathematics, on the contrary, it is possible to have a quasi universal generation, e.g. the generation of a line from a point. This makes it clear that the science of nature has somewhat the same character of singularity as moral science. In these two fields alone is it possible to have history.

As the student gets deeper into the realm of concrete singularity his science becomes conditioned by a constantly increasing multiplicity of elements. (129(In this it becomes remarkably similar to moral science. And just as in the field of concrete human actions the multiplicity of elements is so great that action remains possible only because man can override this multiplicity by a deliberate act of the will, so in the parts of natural doctrine which are deeply immersed in concretion, experience is conditioned by such a multiplicity of elements that science becomes possible only because the scientist overrides this multiplicity by deliberate fiat.

All this makes it clear why physical science as it advances towards concretion soon issues into a purely dialectical extension. This happens both because of the materiality of natural things and because of man's way of knowing them. It is interesting to note that if we consider the whole range of natural doctrine from the highest generality to the ultimate concretion the part which has a truly scientific character is small indeed in comparison with the part whose character is merely dialectical. It is also interesting to point out that the passage of Aristotle which we used to introduce this problem is taken from a treatise which is already far along the road to concretion.

Now it is highly significant that no other speculative science has such a dialectical extension. Theology, metaphysics, logic, arithmetic and geometry can pursue their course in strictly scientific fashion. This does not mean, of course, that no probable factors enter into these studies. It means that in these sciences there are no sections whose whole structure is dialectical. Of all the speculative sciences this is characteristic of the study of nature alone.

But at the same time it is also characteristic of practical knowledge. In moral philosophy as soon as we leave the most general principles necessity likewise peters out into probability.(150) That is why St.Thomas often repeats that moral philosophy proceeds "figuraliter, idest verisimiliter." And the closer the moral philosopher draws to concretion, the less normative his science becomes. Nevertheless, the very nature of his science forces him to continue along this road, exploring the realms of sociology, economics, etc, always pressing forward towards greater concretion. Once again as in the study of nature, the part of the doctrine which enjoys strict scientific necessity is small indeed in comparison with the part which possesses only probability.

Our final point of comparison between natural doctrine and practical knowledge brings us back to something considered at the beginning of this chapter. We saw that as the scientist draws closer to the ultimate concretion, his attempts to lay bare the secrets of nature make it increasingly necessary for him to operate upon nature, to refashion it and reconstruct it. In this way physical science gradually takes on the aspects of an art. At the same time man's practical power over

nature increases. And not only does his power increase, but at the same time his ars cooperativa naturae, as in the cases of the arts of medicine and hybridization, for example, increases. And in this man knowingly and through his skilful action pursues a terminus that in itself is natural.(151)

These few ideas on the relation between the science of nature and practical knowledge must suffice for the moment. Later chapters will give them fuller embodiment. But it is worth while pointing out here what an important bearing all this has upon the problem of mathematical physics. For few things could seem more diametrically opposed than mathematics and practical knowledge. Yet it is to this cosmos, which in so many ways presents such striking resemblances to the object of practical knowledge, that mathematics is applied.

6. Specification and Method

From this general consideration of the specification of the sciences a conclusion must be immediately drawn which is of extreme importance for our purpose. It is this: the specification which sets off the various distinct sciences is neither arbitrary nor

fluid; it is something very objective and definite. As a consequence, each specifically distinct science has a special character of its own which the other sciences cannot share. Each science has its own particular questions and its own particular answers; it has principles that are peculiar to it; it has its own way of demonstrating; it has a unique method.(132)

Saint Thomas brings out this point in a general way in his Commentary on the De Trinitate when, after explaining the distinction between physics, mathematics and metaphysics, and pointing out how each of these sciences terminates in a different cognitive power, he concludes: "Et propter hoc peccant qui uniformiter in tribus speculativae partibus procedere nituntur."(135) As Maritain has remarked, these words should be written in letters of gold over the doors of every university.(134)

In his Commentary on the Posterior Analytics, Aquinas presses this point home with greater precision and greater insistence. In commenting on Chapter XII he devotes a whole lectio(136) to showing that each science has its own particular type of questions and answers and disputations. And he points out how this follows from the very specific character of the science. For,

as we have seen, the sciences are specified by the type of propositions they use as principles of their syllogisms. But a scientific question and a scientific proposition are substantially the same, and differ only in the mode of expression. Since, therefore, each science has its own particular type of principles, it will necessarily have its own particular type of questions. And so Aquinas concludes: "Non ergo quaelibet interrogatio est geometrica, vel medicinalis; et sic de aliis scientiis."(136) Since an answer must be in the same genus as the question to which it replies, it follows that each science has its own type of answers. And consequently St. Thomas remarks: "Non contingit de quolibet interrogato respondere: sed solum de his quae sunt secundum proprias scientias."(137) It likewise follows that each science has its own type of disputation, since disputations proceed by questions and answers. And in order to press this general point home with more precision he adds to this lectio another lectio in which he shows that each science has its own peculiar types of deception and ignorance.(138)

But of even greater significance for our purpose is his commentary on Chapter VII(139) wherein he proves that each science demonstrates by means of its own

proper principles, and that consequently the demonstrations of one science cannot be used to demonstrate something in another science. He writes:

> In illis scientiis, quarum est diversum genus subiectum, sicut in arithmetica, quae est de numeris, et geometria, quae est de magnitudinibus, non contingit quod demonstratio, quae procedit ex principiis unius scientiae, puta arithmeticae, descendat ad subiecta alterius scientiae, sicut ad magnitudines, quae sunt subjecta geometriae. (140)

And he goes on to give the reason: the principles and the conclusions of a scientific syllogism must be in the same genus, for the principles illiminate the conclusions; the latter are in fact precontained in the former.

This doctrine taken as it stands here immediately gives rise to serious epistemological difficulties. It seems to throw up rigid and insurmountable barriers between the sciences in such a way that one science cannot influence another, except perhaps in a very extrinsic fashion. And has not modern science given the lie to any doctrine that would establish barriers of this kind? Must we conclude that it is illegitimate to ask geometrical questions in terms of arithmetic or to seek to demonstrate geometrical propositions by means of arithmetical principles: If so, what about analytical geometry? And - - to come directly

to the issue with which we are concerned - - is it illegitimate to raise questions about physics in terms of mathematics or to arrive at conclusions about nature through mathematical demonstrations? If so, what about mathematical physics? There is not a modern scientist or philosopher of science who would not immediately rejent any doctrine which would call into question the legitimacy of such procedures. And Emile Meyerson terms the doctrine taught by Aristotle in the chapter we have been considering: "si choquante pour le sentiment de l'homme moderne." (141)

Fortunately, there is no reason to take scandal. All difficulties vanish when the Chapter is read in its entirety in the light of the commentary of St. Thomas, and in conjunction with the whole content, particularly Chapter XIII where Aristotle and St. Thomas consider the problem of the subalternation of the sciences. And this whole context must, of course, be integrated with their other writings which treat of this question, notably the passage from the second book of the Physics cited in Chapter I. This full and integral reading not only dispels all difficulties but it leaves us with a profound admiration for Aristotle and Aquinas whose analyses remain

accurate to this day.

In lectio 21 of the Posterior Analytics, after explaining that each science has its own particular questions, St. Thomas goes on to give an example taken from geometry.(142) In giving this example he brings in the case of the science of optics which is subalternated to geometry, and he points out that it is legitimate to ask geometrical questions in optics precisely because it is subalternated to geometry and to that extent integrated with it. And he concludes:

> Et quod dictum est de geometria, intelligendum est de aliis scientiis: quia scilicet propositio, vel interrogatio dicitur propria alicuius scientiae, ex qua demonstratur vel in ipsa scientia, vel in scientia ei subalternata.

In lectio 15, to the text cited above in which he says that arithmetical demonstrations cannot be employed in geometry he immediately appends this important qualification:

> ... nisi forte subiectum unius scientiae continetur sub subiecto alterius, sicut si magnitudines continentur sub numeris (quod quidem qualiter contingat, scilicet subiectum unius scientiae contineri sub subiecto alterius, posterius dicetur). Magnitudines enim sub numeris non continentur, nisi forte secundum quod magnitudines numerorum sunt.(143)

In this passage written centuries before Descartes St.Thomas

explicitly allows the possibility of a treatment of geometry in terms of arithmetic.

In giving the reason why demonstrations must be in the same genus, St. Thomas takes pains to explain and qualify his doctrine with great accuracy:

> Quare manifestum est quod necesse est, aut esse simpliciter idem genus, circa quod sumuntur principia et conclusiones, et sic non est descensus, neque transitus de genere in genus: aut si debet demonstratio descendere ab uno genere in aliud, oportet esse unum genus sic, idest quodammodo. Aliter enim impossibile est quod demonstretur aliqua conclusio ex aliquibus principiis, cum non sit idem genus vel simpliciter, vel secundum quid.
> Sciendum est autem quod simpliciter idem genus accipitur, quando ex parte subiecti non sumitur aliqua differentia determinans, quae sit extranea a natura illius generis; aliquo si quis per principia verificata de triangulo procedat ad demonstrandum aliquid circa isosceles vel aliquam aliam speciem trianguli. Secundum quid autem est unum genus, quando assumitur circa subiectum aliqua differentia extranea a natura illius generis; sicut visuale est extraneum a genere linneae et sonus est extraneus a genere numeri...
> Cum autem huic coniunxerimus quod diversae scientiae sint circa diversa genera subiecta; ex necessitate sequitur quod ex principiis [illegible] in the vnius scientiae non concludatur aliquid in alia scientia, quae non sit sub ea posita...
> Et similiter, quod est unius scientiae non habet probare alia scientia, nisi forte una scientia sit sub altera; sicut se habet perspectiva ad geometriam, et consonantia vel harmonica, idest musica, ad arithmeticam.(144)

A casual reading of these passages might give the impression that St. Thomas contradicts himself. First he denies the possibility of using the demonstrations of one science, such as arithmetic, in another science, such as geometry. In the next breath he seems to admit the possibility. There is no contradiction here. He is merely trying to insist upon the fact that in order to unite things correctly one must first distinguish them carefully, that union without accurate distinction can only result in confusion. He begins, therefore, by insisting upon the distinct character of the sciences, each of which has its own peculiar mode of demonstration. From this he concludes that per se, that is, absolutely speaking, the demonstrations of one science cannot be applied promiscuously to other sciences. Having laid down this basic principle he goes on to explain that under certain conditions one science may be brought to bear upon another, in the measure in which one can be to some extent integrated with the other through the process of subalternation. But in the union effected through this subalternation neither of the sciences loses its proper character. The union of mathematics and physics does not mean that physics is mathematics,

or that mathematics is physics. Saint Thomas is very careful to keep before our minds the fact that the demonstration of a geometrical proposition through arithmetical principles is a process that is essentially different from the demonstration of a geometrical proposition through geometrical principles. All too many modern scientists and philosophers of science have allowed themselves to lose sight of this fact. That is why their union is a confusion.

And now, having seen the principles which govern the distinction of the sciences, we must turn our attention to the problem of their subalternation.

Let us try to give some [illegible]

CHAPTER THREE

THE SUBALTERNATION OF THE SCIENCES

1. The Species of Subalternation.

In this question of subalternation we are touching upon one of the most basic and pivotal notions in the philosophy of science. That is why it is imperative to handle it with as much incisiveness as possible. For the ancient Thomists subalternation had a rather well defined meaning. But unfortunately not all modern Thomists have kept its outlines clear and sharp, nor have they taken sufficient pains to keep distinct the various ways in which the general notion of subalternation may be applied. The question has been handled with considerable looseness and ambiguity, and the result has been confusion. Let us try to circumscribe the meaning of the word as closely as possible.

Subalternation is sometimes defined in terms of the application of one science to another, or the

dependence of one science on another, or the subordination of one science to another. Its notion involves all of these things, but they do not adequately explain its meaning. In the first place, not every case of the application of one science to another is a case of subalternation. For example, in philosophy of science there is a kind of application of metaphysics to experimental science. But this does not involve the subalternation of experimental science to metaphysics. The philosophy of science is a purely metaphysical study, for, as we pointed out in Chapter I, it pertains to wisdom to make a critique of the nature of all the sciences including itself.(1) Secondly, subalternation is not coterminous with dependence. For example, theology, in so far as it makes use of philosophy, may in some sense be said to be dependent upon it. But it is not subalternated to it.(2) Thirdly, the notion of subordination is not sufficient to explain the meaning of subalternation. For, philosophy is subordinated to theology, but it is not subalternated to it.(3) Moreover, all practical sciences is in some way subordinated to speculative science, but this subordination does not necessarily involve subalternation. It is true that some practical sciences, such as medicine, agriculture, etc. are subalternated to the

sciences of nature, but that is because of the peculiar character of the relation that obtains between them, as we shall presently explain.

One of the difficulties encountered in the problem of subalternation arises out of the fact that the term is used in a variety of ways. Perhaps the best way to arrive at the positive meaning of the term is to begin by considering the different ways in which one science may be subalternated to another. John of St. Thomas distinguishes three types of subalternation.(4) One science may be subalternated to another either by reason of its end, or by reason of the principles it employs, or by reason of the subject it considers. Let us consider briefly each of these types.

Subalternation that derives from an end pursued is, as the very terms suggest, proper to the practical order; it is found in the practical sciences and in the arts. When the end of one science, though truly an end within its own order, is subordinated to the end of a higher science in such a way that it is controlled and directed by it, the first science is said to be subalternated to the second. Thus, for example, military science is subalternated to

political science. It is important to note that the first end must be truly an end within a certain order, for if it is only a means, if the higher science uses it merely as an instrument there is no real distinction of sciences and hence no subalternation. In this first type we are dealing with subalternation in a very broad and improper sense. For, subalternation implies the dependence of one science upon another with respect to the manifestation of truth, and very often when one science is subalternated to another by reason of its end there is no dependence of this kind, but rather dependence with respect to use, control, direction, and command, - - something akin to what is found in the interrelation of the virtues, as for example in the case of charity's command over temperance. And this follows from the very nature of the practical order, whose object is not the true as true, nor even the good as true, but the good as good. It is only in the speculative order that subalternation in the proper sense of the term is found, for the object of this order is always the true, and consequently subalternation in this order involves a manifestation of truth. We are particularly interested in the subalternation of the speculative sciences.

One speculative science may be subalternated to another in two ways: either by reason of its principles alone or by reason of its subject. The first case is had when a lower science borrows from a higher science the principles necessary to illuminate its own domain, and thus becomes dependent upon it. But in order to have subalternation of this kind in the full sense of the term the dependence must be necessary and essential, that is to say, the lower science must be lacking in per se evident principles within its own domain, and thus be forced to reach up to a higher science to have its principles made evident. This type of dependence is found in the subalternation of supernatural theology to the science of the blessed. Theology does not resolve its demonstrations into principles that are per se evident. For the theologian must accept his principles on faith. But these principles accepted by faith have their intrinsic evidence in a higher science -- the science of the blessed in heaven. It is in this higher science that they find their manifestation and their proof. That is why theology is essentially subalternated to the science of the blessed.

It is extremely important to insist upon the difference between this kind of dependence and the kind of

dependence that philosophy of nature and the other sciences have upon metaphysics. It is true that in some sense all of the sciences receive their principles from metaphysics, for as St. Thomas says, "ipsa (metaphysica) largitur principia omnibus aliis scientiis."(5) Nevertheless, the lower sciences do not depend upon metaphysics for the evidence of their principles. They are capable of resolving their demonstrations into per se evident principles which are proper to them. They do not have to turn to metaphysics to have the truth of their principles made manifest or proved. It is true that metaphysics explains the principles of the other sciences and defends them by a reduction ad impossibile, but it does not prove them in an a priori fashion. The principles of the other sciences come under the influence of those of metaphysics only in the sense that metaphysics is the most universal and the most basic of all the sciences. And even though it has become common for authors to state that the principles of philosophy of nature are contractions of the principles of metaphysics (e.g. that the principle of the composition of mobile being of matter and form is a contraction of the division of being into potency and act), we feel that such statements need qualification. For there is a world of

difference between the way in which the particular principles governing a certain type of motion are contractions of the general principles of motion, and the way in which the principles of the philosophy of nature are contractions of metaphysical principles. For, as we saw in the two, in the latter case there is not merely a question of the application of the more general to the more specific; there is a question of two different orders. It is a serious error to confuse the two types of dependence described in these last two paragraphs.

It is true that the other sciences may sometimes use metaphysical principles in their demonstrations. It is likewise true that they may sometimes employ principles taken from the science of logic. But this amounts to no more than an occasional borrowing from these other sciences; it merely means the use of an extrinsic proof. All this explains why the dependence of the other sciences upon metaphysics and logic is not subalternation in the full sense of the word. And if the term subalternation is applied to this kind of dependence it should be made very clear that it is only a question of subalternation in a very partial and limited sense. (6)

Now for our purpose, it is not subalternation by reason of the principles alone that is of particular interest, but subalternation by reason of the object. In this third type we have subalternation in the most perfect sense of the word. John of St. Thomas says: "Tertius modus ... induxit propriissimam subalternationem." (7) We must try to see why this is so.

This third species of subalternation arises when the object of one science falls under the object of another science. But as we pointed out in Chapter I in our discussion of the fifteenth lectio of the first book of the Posterior Analytics, one object may fall under another in two ways. First of all, it may merely be a question of a more specific object being contained in a more generic object, in the way in which, for example, animated mobile being falls under mobile being. In this case it is evident that there is no real distinction of science and hence no possibility of true subalternation. Every science explains its object by division as well as by definition, and consequently in order to have the formal distinction of science that is required for subalternation, it is not sufficient that one object add an essential specific difference to the other. And this explains why many of the apparently hybrid

sciences to which we alluded at the beginning of Chapter II (e.g. astro-physics, bio-chemistry, etc.) do not involve true subalternation, since it is merely a question of the union of two branches of the same science. There is, consequently, a world of difference between the hybrid character of these sciences and that of mathematical physics in which physics is truly subalternated to mathematics.

Because the subalternated science must be extrinsic to the subalternating science, the difference which the object of the one adds to the object of the other must be extrinsic and accidental. An example will make this point clear. Let us take the geometrical notion of "line". We may add to this notion in two ways. First of all, we may add the proper specific differences "straight" and "curved", and thus arrive the two specific objects, "straight line" and "curved line", both of which fall under the generic object, "line." By doing this we do not arrive at any new science, since the science which deals with a certain genus necessarily deals with all the proper species which fall under it. But it is also possible to add to the notion of line the extrinsic and accidental difference "visual", and thus arrive at a new object, "visual line".

This new notion is not a proper species of the generic geometrical notion of line. Hence it does not fall under the science of geometry in the sense of being a part of its object. In fact it constitutes a new science, the science of optics, known to the ancients as "perspective". This new science, while not falling under geometry in the sense of being a part of it, does come under it in some way, since the notion of line which is compounded with the notion of visual to constitute its object is borrowed from geometry. In other words, optics is subalternated to geometry by reason of its object.

Perhaps another simple example will clinch the point we are trying to make. We may add to the generic arithmetical notion of number the two proper essential differences "rational" and "irrational", and thus arrive at two numerical species, both of which pertain essentially to the object of arithmetic. But we may also add to the notion of number the extrinsic and accidental notion of sound and thus arrive at a compound object which constitutes a new science, distinct from arithmetic, but subalternated to it -- the science of music.

How subalternation by reason of the object

always involves at the same time subalternation by reason of the principles. This should be fairly evident from the examples just cited. For, since the formal object of the subalternated science is constituted by the addition of an accidental difference to the object of the subalternating science, the subalternated science cannot treat its object and prove its properties except by having recourse to the conclusions of the subalternating science. But subalternation by reason of the principles does not always involve subalternation by reason of the object. The contrast between the way theology is subalternated to the science of the blessed and the way optics is subalternated to geometry brings this point out with sufficient clarity. As we saw, supernatural theology must reach up to the science of the blessed in order to find the evidence of its principles. Nevertheless, its object is not constituted by the addition of an accidental difference to the object of the science of the blessed. It is, in fact, the very same object viewed under two different lights: the light of faith on the one hand, and the light of vision on the other. But the difference between geometry and optics does not consist merely in two different ways of viewing the same object. In the first

case we have a simple notion that prescinds from all sensible matter. In the second case we have a compound object made up of this simple notion plus an accidental element which involves sensible matter. There is an enormous difference between these two types of subalternation. In the first type, the subalternated science remains a simple science. In the second type, it becomes a complex science, a hybrid science, a scientia media, because its object is compounded of elements which involve two different levels of intelligibility.

The three fundamental types of subalternation just described are the only ones mentioned by John of St. Thomas in the article cited above. We may well wonder whether the list is exhaustive. For St. Thomas in his Commentary on the De Trinitate (8) gives us a case of subalternation which does not seem to fall under any of the three groups listed by his disciple. We are referring to the case already mentioned earlier in this chapter in which the practical sciences of medicine, agriculture, etc. are subalternated to the speculative science of nature. We pointed out that this subalternation does not arise merely from the subordination that all practical science has to speculative science, but from the special

character of the dependance which these few practical sciences have upon the science of nature. St. Thomas brings out the nature of this special relation with great clarity and precision:

> Quamvis enim corpus sanabile sit corpus naturale, non tamen est subjectum medicinae, prout est sanabile a natura, sed prout est sanabile per artem. Sed quia in sanatione quae fit per artem, ars est ministra naturae, quia ex aliqua naturali virtute sanitas perficitur auxilio artis, inde est quod propter quid de operatione artis oportet accipere ex proprietatibus rerum naturalium. Et propter hoc medicina subalternatur physicae, et eadem ratione alchimia, et scientia de agricultura, et omnia huiusmodi. Et sic relinquitur, quod physica secundum se, et secundum omnes partes eius est speculativa, quamvis aliquae operativae subalternentur.(9)

It does not seem possible to fit this type of subalternation directly into any of the three groups described above. It is not a case of subalternation by reason of the end, for we do not have one practical science subordinated to another practical science. Nor is it a question of subalternation by reason of the principles, for a practical science cannot receive its proper principles from a speculative science. Since the end of a practical science is not to know "why" but "how", it cannot receive a reason why or a propter quid from a speculative science. Finally, there is no possibility here

of subalternation by reason of the object, for elements from a practical science cannot be compounded with elements taken from a speculative science to constitute the object of a simple, unified science. As a matter of fact John of St. Thomas, after explaining the three types of subalternation, explicitly denies that medicine is subalternated to natural science: "Medicina (agit) de corpore sanabili, et tamen non subalternatur Philosophiae, quae agit de corpore."(10) From the context, however, it is evident that he is merely denying the possibility of subalternation by reason of the object. And even though the way in which medicine and agriculture are subalternated to natural science does not fit directly into any of the three groups listed by John of St. Thomas, it may be reduced to a case of the second group. For while it is true that a practical science cannot receive its principles from a speculative science, the principles of medicine and agriculture are completely determined by the principles of natural science because of the unique character of the relation existing between these sciences. Perhaps nowhere can the Aristotelian adage: Ars imitatur naturam be applied with such fullness as here. In fact, the imitation is so perfect that in a certain sense it

results in an identification, for in medicine and agriculture, the works of art must be at the same time works of nature.

It would seem that if the concept of subalternation is conceived as embracing all of the various cases we have described it can hardly have a strict unity. Nevertheless, there are two kinds of subalternation in which the concept is realized in its proper and strict sense, and in which it has a definite unity. We refer to subalternation by reason of the principles in which there is an essential relation of dependence between the subalternated science and the subalternating science, that is to say, when the former receives its proper principles from the latter, and to subalternation by reason of the object. When the ancient Thomists speak of subalternation, it is usually this strict and proper sense of the concept that they have in mind, and it is in this sense that we shall speak of it from now on.

And now, having reduced the notion to this definite meaning, it remains for us to explain in what its essence consists. But before pursuing this analysis it is worth while pausing at this point to remark that every effort should be made to maintain a clear cut

distinction between the various kinds of subalternation we have been describing. As we pointed out at the opening of this chapter, this has not always been done by modern Thomists. We are being told by more than one contemporary writer for example that philosophy of nature is a scientia media, born of a union of the first and third degrees of abstraction, or, even worse, arising out of the application of metaphysics to the data of empirical science.(11) And we consider it extremely misleading, unless all the necessary qualifications and distinctions are made, to insist, as some authors do, that in modern times mathematics has come to occupy the same position in relation to the experimental sciences that metaphysics held for the ancient Thomists.

2. The Essence of Subalternation

The intrinsic nature of subalternation follows from the intrinsic nature of science itself. Science is certain knowledge of things in their causes, and for the human intellect this means knowledge arrived at by a process of demonstration. Now knowledge that is arrived at by demonstration is never self-evident knowledge.

Conclusions do not have their evidence from themselves, but from something else, namely from the immediately evident principles from which they have been derived. That is why the intellectual virtue of science is essentially dependent upon another intellectual virtue, known as the intellectus principiorum, which is the habitus that enables the mind to grasp immediately the truth of self-evident principles. Now the essential difference between a subalternated science and a science that is not subalternated is that the habitus of the latter is in immediate continuity with the habitus principiorum, whereas the habitus of the former is only mediately in continuity with it, through the habitus of a higher science, known as the subalternating science. (12)

In other words, no science is a science in and by itself, but in and by its continuity with a superior habitus, for without this continuity its conclusions cannot have the certitude that is necessary for scientific knowledge. A science that is not subalternated is a science that is in direct continuity with the habitus principiorum from which it immediately derives the evidence of its conclusions. On the other hand, a subalternated science is one that is in direct continuity

with the habitus of a superior science, and only through this habitus is it in continuity with the habitus principiorum.

At this point it will be helpful to draw a contrast between the way supernatural theology is subalternated to the science of the blessed and the way other sciences are subalternated -- not because we are particularly interested in the subalternation of theology, but because the contrast will serve to accentuate the characteristic features that are found in the intermediary sciences in general and in mathematical physics in particular. In the subalternation found in all the other sciences besides theology, the proximate principles of the subalternated science are conclusions demonstrated by the subalternating science.

> ... scientia subalternata non utitur principiis aliarum scientiarum, sed conclusionibus: assumit enim principia quae probantur a scientia superiori tamquam conclusiones, non autem principiis superioris scientiae utitur resolvendo usque ad principia per se nota. (13)

principles not to be evident without their being possessed. When the subalternating science does not coexit in the same intellect along with the subalternated science, these conclusions are taken on faith. But this does not mean that in this case the principles of the subalternating

science are taken on faith. For the intellect which possesses the subalternated science may possess the principles of the subalternating science by means of the habitus principiorum, without possessing the habitus of the subalternating science itself. In this connection John of St. Thomas writes:

> ... in scientiis naturalibus non potest verificari quod ipsa principia per se nota ipso lumine principiorum in superiori scientia, sint tantum credita, et non per se nota in inferiori: quia quod est per se notum lumine principiorum, omnibus est per se notum; et principia quanto sunt superiora, et ad scientiam superiorum pertinent, tanto sunt magis nota omnibus propter suam universalitatem.(14)

This only refers, of course, to principles that are self-evident, and not to the postulates which a science may take as its principles. In this kind of subalternation there are two points to be noticed about the proper principles of the subalternated science; first, they are not evident; secondly, they are mediate, that is to say, they are the fruit of demonstration from principles that are evident. These two points are not identical, for it is possible for principles not to be evident without their being mediate. And in this distinction we find a fundamental difference between the kind of subalternation we have just been considering and the kind that is found in supernatural theology.

The proper principles of theology are not evident; but not all of them are mediate, since some are as first reasons, and others are truths consequent upon these reasons. Now as Cajetan points out, (15) although both the element of inevidence and that of mediacy are ordinarily considered to pertain to the essence of subalternation in some way, the former pertains to it in a formal way, and the latter only in a material way. Hence, in order to have true subalternation it is not absolutely necessary that the proper principles of the subalternated be conclusions; it is sufficient that they be not evident. In fact, John of St. Thomas maintains that in theology's use of principles that are not conclusions there is a fuller kind of subalternation than that found in the natural sciences where all the proper principles of the subalternated science are necessarily conclusions. For, whereas in the latter case, as we pointed out above, at least the principles from which the conclusions are drawn are evident, in the former case the fundamental principles are in no way evident. (16)

But here it is important to distinguish between two kinds of continuity, which for want of better terms we shall call objective and subjective. When the continuity is considered from the point of view of the objects that

the science is about it is objective; when it is considered from the point of view of the scientist it is subjective. Another way of expressing the same idea is to say that objective continuity is the continuity that a science has by its very essence, while subjective continuity is the continuity that it has because of its actual state. When a subalternated science is in its perfect state there is subjective as well as objective continuity. But when it is in an imperfect state, subjective continuity may be lacking. And here it must be pointed out in passing that when Thomists raise the question about whether or not a certain subalternated science is in continuity with the subalternating science, it is to subjective continuity that they are referring, for, obviously, there can be no question about objective continuity since it is a necessary condition for the very possibility of subjective continuity. But perhaps the best way to explain this distinction is by means of an example. The science of optics necessarily has objective continuity with the science of geometry, that is to say, its proximate principles are geometrical conclusions, which in turn have their evidence from their continuity with self-evident principles. But from the point of view of the student of optics this continuity may

or may not exist. It exists if he is a mathematician as well as a student of optics. It does not exist if the geometrical conclusions which he applies to his particular matter are merely accepted by him on the authority of a mathematician without their intrinsic evidence being grasped. From this it follows that the habitus of the proximate principles of a subalternated science is *per se* the habitus of the subalternating science. *Per accidens*, however, it may be a matter of authority alone.

In this distinction of the two kinds of continuity we have the solution to a problem to which John of St. Thomas gives considerable attention.[17] The problem is this: when subjective continuity does not actually exist, is it possible for the subalternated science to be a true science? At first glance it would seem not. For scientific knowledge is necessarily certain knowledge. And how can knowledge be certain if it is reducible merely to principles which are held on authority and not to *per se* evident principles? Does not St. Thomas write: "quaecumque sciuntur proprie accepta scientia, cognoscuntur per relationem in prima principia, quae per se praesto sunt intellectui."[18]

As we have just said, the correct solution of this problem lies in the distinction between subjective and objective continuity. Even when subjective continuity is lacking, objective continuity is always there, and that is sufficient to insure the truly scientific character of the subalternated science. For objective continuity means that the proper principles of the subalternated science are de facto demonstrated in the subalternating science, and thus there is the essential connection between the subalternated science and self-evident principles which St. Thomas demands in the text just cited.

This problem has particular significance for the science of theology, which, in this life, is based completely on faith. But it also has relevance for the question in which we are interested. For we can imagine the hypothetical case of a student of nature who, though unacquainted with the pertinent mathematical demonstrations that are presupposed, might accept the mathematical conclusions he needs on authority and employ them in his interpretation of natural phenomena. The conclusions concerning nature that he would be able to arrive at by using the borrowed mathematical conclusions as principles would express objective truth, even though they could not be called

scientific truths on the part of the student himself.

From this we may conclude that a subalternated science is specifically the same scientific habitus whether there is subjective continuity with the subalternating science or not. For even when subjective continuity is lacking, the objective continuity establishes an essential relation between the subalternated and the subalternating science. It is this essential relation that determines the nature of the subalterned habitus. And this essential relation demands completion by subjective continuity. Hence, as long as subjective continuity is lacking the habitus of the subalternated science is in an imperfect state. But when it is acquired, no new habitus is born; the old habitus is merely brought to fullness and perfection. The following lines of St. Thomas throw light upon this subtle point:

> ... qui habet scientiam subalternatam, non perfecte attingit ad rationem sciendi, nisi in quantum eius cognitio continuatur quodammodo cum cognitione eius, qui habet scientiam subalternantem. Nihilominus tamen inferior scienc non dicitur de his, quae supponit, habere scientiam, sed de conclusionibus, quae ex principiis suppositis de necessitate concluduntur.(19)

At this point we must turn our attention to a highly significant passage of John of St. Thomas:

> ... non facit subalternationem simpliciter hoc quod est mutuari aliquod principium ab aliis scientiis, ad procedendum ex illo tamquam ex principio extraneo et mutuato. Ratio est, quia subalternatio propria et simpliciter, requirit quod aliqua scientia ex propriis principiis et intrinsecis non possit resolvere in principia per se nota; sed pro evidentia suorum principiorum necessario debeat recurrere ad aliquam aliam scientiam, quae talem evidentiam faciat. Si autem utitur principiis aliarum scientiarum tamquam extraneis et mutuatis, et in illis solum recurrit ad scientiam extraneam pro illorum evidentia: non manet subalternata intrinsece; quia quantum ad propria et intrinseca principia non accipit evidentiam ab alia scientia, sed solum quoad principia extranea. Et ex hoc judicanda est subalternatio propria et intrinseca: scilicet an inveniatur in principiis intrinsecis et propriis alicuius scientiae, an solum in externis et mutuatis;(20)

These lines have two obvious references. In the first place they refer to a point made by John of St. Thomas in the Cursus Philosophicus which we have discussed earlier in this chapter: an occasional and extrinsic borrowing of principles from other sciences, such as metaphysics and logic, does not constitute subalternation in the strict sense of the word. In the second place, they refer to the immediate context in which the author shows that theology cannot be subalternated to philosophy even though it uses philosophical principles in its demonstrations, for first of all it does not take them as its own proper principles,

and secondly it uses them only after having judged them in its own supernatural light and elevated them in some way to its own level, and thus the whole essence of the demonstration rests formally and ultimately upon the supernatural principle.

But it is not particularly because of these immediate references that we have introduced this passage here. Rather it is because some of the statements in it give rise to a problem which touches the very essence of the type of subalternation found in mathematical physics.

As this passage of John of St. Thomas suggests, the ancient Thomists do not seem to have considered what we shall call dialectical subalternation, that is to say, subalternation in which the subalternating science does not give to the subalternated science in an intrinsic and adequate way the evidence of the principles that are proper to the subalternated science -- one in which there is not realized a sufficiently perfect continuity between the two disciplines in question to permit the formation of a science in the strict sense of the term. Now this is the type of subalternation that is actually found in mathematical physics. And that is why we must develop this point a little further.

The medieval Thomists recognized the existence of mathematical physics, and they accurately analyzed its nature as an intermediary discipline that involves the fullest kind of subalternation -- subalternation by reason of the object. They carefully distinguished this type of subalternation from that found in theology where the principles alone are involved. Nevertheless, for them there was a fundamental parity between these two types of subalternation. Just as there was a perfect continuity between the principles of theology and those of the science of the blessed, so there was a perfect continuity between the principles of physics and those of mathematics -- at least sufficiently perfect to permit mathematical demonstrations to be applied adequately to physical phenomena.

We are referring here to a point already mentioned in Chapter I, where we explained that for Aristotle and the medieval Thomists mathematical physics could constitute a science in the strict sense of the term because physical entities realized a sufficiently perfect conformity with mathematical entities to allow for the former to be treated in terms of the latter in strictly scientific fashion. The reason why they held this view

was that they were without refined experimental instruments, and had to depend upon sense experience. Now rough sense experience is extremely illusive. It often gives the impression that things in nature have a perfection which as a matter of fact they lack. The sense of touch may convey the notion that a surface is perfectly flat; the sense of sight may give the impression that a physical sphere is a perfect sphere. Consequently, when there is nothing else to go on but this rough experience one is easily led to feel justified in positing the hypothesis that physical lines and figures reasonably approach mathematical perfection.

The refinement of our modern instruments has emphasized the gap between physical and mathematical entities. All of our measurements are only approximative. For this reason it now seems necessary to hold that mathematical physics is merely dialectics and not a strict science. That is why the subalternation involved in it is purely dialectical.

But perhaps we should immediately add that we are considering the question here merely from the point of view of the knowledge of which the human intellect is

capable in its present state. For we see no reason to exclude a priori the possibility of the existence in nature of entities whose perfection approaches mathematical perfection sufficiently to allow for their being treated in terms of mathematics in a strictly scientific way. We have no means at our disposal to make it possible for us to arrive at this perfection, but perhaps the knowledge of this perfection is possible for the angelic intelligences, or even for the human intelligence in a superior state. If this should be true, mathematics would be able to provide a strictly scientific propter quid for natural phenomena.

But perhaps what we have just said about the opinion of Aristotle and the medieval Thomists may give rise to a problem. For if they believed that there existed in nature entities whose perfection came reasonably close to mathematical perfection, why did not such entities fall directly under the object of the study of nature? Why was it necessary to study them in terms of mathematics and construct the theory of scientia media? Why was not the so-called science of mathematical physics nothing but physics? Does not this bring us back to something akin to the opinion of Professor Hanson criticized in the last

Chapter? The answer is that even if the conformity between physical and mathematical entities were perfect, physics would still have to be subalternated to mathematics. For the concrete quantitative determinations of nature, in so far as they remain attached to sensible qualities, are not susceptible of the conceptual elaboration of which mathematical quantity is capable. Quantity is by its very nature more abstract than the sensible qualities, and it has its own reasons prior to those of the sensible qualities, and this would necessarily lead to subalternation.

A few general remarks remain to be made in order to complete our consideration of the nature of subalternation. In the first place, it should be evident from what has already been said that a lower science must be subalternated to a higher science and not vice versa.

> ... quanto scientia aliqua abstractiora et simpliciora considerat, tanto eius principia sunt magis applicabilia aliis scientiis; unde principia mathematicae sunt applicabilia naturalibus, non autem e converso propter quod physica est ex suppositione mathematicae et non e converso, ut patet in XII Caeli.(21)

A higher science may at times use the principles of lower science, but then the dependence is only material and not formal, for the higher science in that case interprets the principles of the lower in terms of its own superior light. (22)

In the Posterior Analytics, St. Thomas gives us an example in which a mathematical proposition is demonstrated in physics:

> Sunt enim quaedam propositiones, quae non possunt probari nisi per principia alterius scientiae; et ideo oportet quod in illa scientia supponantur, licet probentur per principia alterius scientiae. Sicut a puncto ad punctum rectam lineam ducere, supponit geometria et probat naturalis; ostendens quod inter quaelibet duo puncta sit linea media.(23)

It should also be evident that the subalternated science and the subalternating science can coexist in the same subject, that is, in the same intellect. In fact, this coexistence is the normal case, for it is synonymous with the subjective continuity we spoke of above. One could not get very far in analytical geometry without possessing the science of arithmetic and algebra, nor in mathematical physics without a personal knowledge of mathematics. In the case of theology this coexistence or subjective continuity with the subalternating science is impossible in this life but it will be realized in the next, for after death, the habitus of theology will perdure, even though faith has disappeared.

The subalternated science and the subalternating science may also coexist in the same object. That this is true of the material object is obvious. It is also true

of the formal object (ratio formalis quae) but in that case there can be subalternation only by reason of the principles and not by reason of the object. And here we touch upon one of the fundamental differences between the two kinds of subalternation. Theology differs from the science of the blessed only by its ratio formalis sub qua: it studies God under a different light. But the ratio formalis quae, that is the ratio Deitatis is the same. But in the intermediary sciences, not only is the ratio formalis sub qua different (a different type of abstraction), but also the ratio formalis quae, for it is a compound object arising out of the addition of an extrinsic accidental difference to the object of the subalternating science. And in order to understand what this involves we must now analyse more closely the particular kind of subalternation found in the intermediary sciences.

3. Subalternation and Scientia Media

Let us begin our analysis by considering the conditions required in order for a scientia media to exist. We have already touched upon some of them.

In the first place, the object of the subalternated science must contract the object of the subalternating science and add something to it. This addition cannot be an essential, specific difference, for otherwise there will be no formal distinction of sciences. Neither can it be a property that flows essentially from the object of the subalternating science, for the same science which deals with a certain object deals with all the essential properties of it. Consequently, the addition must be an accidental difference which makes the matter of the subalternated science extrinsic to that of the subalternating science. But not any kind of accidental difference is sufficient to constitute a scientia media. For there are some accidental differences which are not the source of any special scientific properties, and as a consequence they are incapable of constituting a new science. For example, there is no scientific fecundity in the addition of the notions of "hot" or "cold" to the mathematical notion of "line". But there is great scientific fecundity in the addition of the notion of "visual", as the science of optics attests. In the same way, the addition of the notion of "visual" to the notion of number does not give rise to special scientific properties, while the addition of the notion of "sound"

does, as is evident in the science of music.

It is important to understand accurately the accidental character of the difference that is added to the object of the subalternating science. This accidental character must not be considered from the point of view of the two sciences themselves, in the sense of there being only an accidental difference between them. As a matter of fact, there is a specific and essential difference between the subalternating and subalternated sciences. Rather, it must be considered from the point of view of the being which constitutes the object of the sciences. In other words, to use scholastic terminology, the difference is accidental to the object, not in esse scibili, but in esse rei. But, as has already been suggested, not every accidental difference in esse rei is sufficient to constitute a mixed science. It must be a difference of such a nature that it gives rise to certain new scientific truths. And these truths must depend for their explanation upon the principles borrowed from the subalternating science.

In other words, the relation between the two elements that are combined to constitute the object of an

intermediary science must be a matter-form relation. The element taken from the superior science plays the role of form, and the element taken from the lower science plays the role of matter. For the subalternating science must illuminate, determine and inform the subalternated science. This is what St. Thomas has in mind when he writes:

> Scientiae mediae, de quibus dictum est, communicant cum naturali secundum id quod est materiale in earum considerationibus, differunt autem secundum id quod in earum considerationibus est formale.(24) Subjectum inferioris scientiae comparatur ad subiectum superioris, sicut materiale ad formale.(25)

In every intermediary science we have an application of the object of a higher science to the object of a lower science. When, for example, in physics we speak of light being propagated in a straight line, the line in question is neither physical alone, nor mathematical alone. It cannot be purely physical, for it is conceived as being perfectly straight. Nor can it be purely mathematical, for it is the physical entity of light that is being propagated. Consequently, it must be both physical and mathematical at the same time.

But such a line does not exist as such in nature. It exists only in the mind. It does not however exist in the mind merely through a simple process of

abstraction. Rather it is born there through an act of composition on the part of the intellect. And it is extremely important to grasp the difference between the composite character of the notion of the physico-mathematical line, and the composite character of the notion of "rational animal", for example. In the latter case the composition is not created by the mind; it is merely discovered by it. That is why it comes into being through a simple process of abstraction. In the former case the composition is created by the mind. It is a priori in the Kantian sense of the term. This is an important point to keep in mind. It will be of vital importance when in Chapter XII we come to discuss how many concessions a realistic philosophy of mathematical physics must make to Kantianism. But lest confusion arise it must be pointed out immediately that even though created by the mind, the union between the two elements is not completely logical. They are brought together by the mind -- but for an objective reason.

Now this composite character of the object of the intermediary sciences gives rise to a serious difficulty for John of St. Thomas.(26) For an object that is constituted by the addition of an accidental difference

can have only an accidental unity, and it seems impossible to have a science that is essentially and specifically one if the object is only accidentally one: "de ente per accidens non datur scientia per se." It is impossible to have an essential definition of a being that is only accidentally one, since the definition gives the quod quid est, which is something strictly one, and a being that is only accidentally one does not consist of a genus and its specific difference. But the unity of a science is determined by the unity of its definitions, since, as we saw in the last Chapter, definitions are the principles of every science.

Perhaps one might be tempted to think that this no longer constitutes a real problem, once we have granted that the intermediary sciences are not sciences in the strict sense of the word, but dialectics. We believe, however, that this would be an illegitimate inference. For though these sciences are dialectical they are not sophistical, and only sophistry deals with ens per accidens. Though they are not sciences in the strict sense of the word, they must proceed ad modum scientiae. Consequently, the problem is still relevant.

John of St. Thomas solves this problem by pointing out that a scientia media does not have as its object simply and directly the composite of the two elements considered as an accidental being. Rather it considers directly only one of the two elements -- not absolutely and by itself, but in so far as it connotes the other and is modified and informed by it. For example, the science of optics, as the very name implies, has as its direct object "the visual". However, it does not consider it independently by itself, but in so far as it is determined by certain mathematical properties. And thus it is possible to consider a certain object as being scientifically knowable per se, and as being the source of certain necessary scientific truths, even though in order to be the source of those truths it requires the accidental addition of an extraneous element. For there are a number of properties which do not flow from an object when it is merely considered absolutely by itself, but only when it is considered as determined, modified, and informed by a certain element, which, though accidental to it, is absolutely necessary in order for these properties to arise. For example, there are certain properties which flow from the notion of sound when it is considered not by

itself alone, but as determined by number. In other words, although the union between the two elements is accidental, the connotation is not accidental, since by means of it certain necessary properties are revealed. Perhaps a simple analogy will add clarity to this point. Paternity is something accidental to man in the sense that not all men are necessarily fathers. Nevertheless, a number of essential properties flow from the notion of man when it is considered precisely as connoting the notion of paternity, which do not arise when it is considered independently of this determination.

It must be noted here in passing that it is precisely because the mathematical element enters into the object of mathematical physics by way of mere connotation that the role of mathematics in physics is essentially functional and instrumental.

Now since the object of a mixed science is a composite of elements taken from different levels of [illegible] intelligibility, the question arises whether the abstraction employed in it is dual, or specifically one. John of St. Thomas explains that it is only one, and that is a special intermediary abstraction that stands in between the two levels of intelligibility from which the elements

have been borrowed, and that participates in the nature of both.

> Quod vero additur de Musica et aliis scientiis subalternis, respondetur in illis non esse duplicem abstractionem, sed unicam, cuatenus principia superioris scientiae ex applicatione ad tales materias redduntur minus abstracta et consequenter pertinentia ad diversam speciem in genere scibilis, et illa abstractio, quam induunt in tali materia, unica est, et ideo aliquid participant de utrisque, unica tamen abstractione, sicut medium unum existens dicitur participare ab extremis.(27)

The significance of the Thomistic doctrine of *scientia media* has not always been correctly understood. Thus, for example, Professor Salmon writes:

> Quant aux sciences mediae, dont on a d'ailleurs beaucoup exagéré l'importance théorique, il ne faut y voir qu'un simple accident historique. Quelques problèmes, plus faciles, avaient reçu des géomètres grecs des solutions fort précises, et donné le caractère mathématique était dès lors plus accusé. On a donc pu croire que la théorie des cordes vibrantes, la catoptrique, l'astronomie, se distinguaient de quelque manière des autres parties moins évoluées de la physique. La différence n'était cependant qu'apparente, comme on l'a soul gné plus haut en faisant valoir des éléments mathématiques implicites des formules rudimentaires du langage commun. On remarquera d'ailleurs historiquement que ces sciences intermédiaires n'interviennent jamais directement dans la classification des sciences, mais sont seulement ajoutées dans les réponses aux objections. Elles ne dérivent pas en effet normalement de la théorie des degrés d'abstraction, mais sont des données de fait, assez gênantes d'ailleurs, que le théoricien intègre comme il le peut dans une synthèse qui ne les prévoyait pas. (28)

We fail to see any foundation for the objection that the intermediary sciences do not enter directly into the classification of the sciences. By the very fact that they are intermediary, they obviously could not be put directly into any one of the three general types of knowledge that are based on the degrees of abstraction. If this is what Professor Salman has in mind when he says that they do not derive normally from the theory of the degrees of abstraction, his observation is perfectly true. But then it is an observation that is utterly lacking in significance. On the other hand there is a sense in which it must be said that they derive essentially from the degrees of abstraction. For it is only by seeing these sciences precisely as intermediary sciences, that is, as combinations of two different levels of intelligibility which arise out of two distinct kinds of abstraction that we can understand their true nature. It is utterly impossible to grasp the meaning of these sciences except in relation to the degrees of abstraction. That is why it is completely false to say that they are mere "données de fait" which the philosopher must force arbitrarily into a synthesis which has no natural place for them. Nor did Aristotle or any of the great Thomists ever show any signs of the embarrassment of which Professor Salman speaks.

We feel that perhaps enough has already been said to show that the intermediary sciences were far from being "a simple historical accident," and that the difference between them and pure natural science is essential and not merely apparent. The further analysis which is to follow will add clarification and confirmation to these points. Mathematical physics is specifically distinct from pure natural science because it contains an essential element taken from the science of mathematics. And yet the introduction of this extrinsic element into experimental physics is necessary and not merely arbitrary. The ancient Thomists recognized clearly both of these points.

As for the remark that the theoretical importance of the intermediary sciences has been greatly exaggerated -- we feel that the contrary is the case. The great epistemological implications latent in this point of Thomistic doctrine and its relevance for modern physics have scarcely been recognized.

4.Scientia Media and Mathematical Physics.

To discover the special characteristics of mathematical physics as a scientia media we must turn to the two

pivotal texts of Aristotle and St. Thomas mentioned in Chapter I. As has already been explained, the text from the Posterior Analytics is introduced in connection with the discussion of the two types of demonstration; demonstratio quia, i.e. demonstration which arrives only at the existence of a fact without being able to give its proper reason and cause, and demonstratio propter quid, i.e. demonstration which gives the proper reason. After pointing out how these two types of demonstration differ in the same science, Aristotle and St. Thomas go on to explain how they differ in different sciences, and first of all in sciences which are subalternated one to the other. And they state that in this latter case it pertains to the subalternating science to know the propter quid, i.e. the proper reason, and to the subalternated science to know the quia, i.e. the simple fact. Both Cajetan (29) and John of St. Thomas (30) insist that in making this statement Aristotle was speaking of something that is special to the kind of subalternation found in mathematical physics and not something that is common to all types of subalternation.

In order to understand why this is so we must try to grasp the difference between a scientia propter quid and a scientia quia. A scientia propter quid is a science

that is explanatory in the strict sense of the word, that is to say a science that assigns the proper reason for things. It is knowledge that is arrived at by a propter quid demonstration, that is to say a demonstration which proves that a property belongs to a subject because of its very essence. A scientia quia is a science which arrives at the fact that certain things exist or happen in a certain way, but it cannot assign the proper reason for the fact. The demonstratio quia which gives rise to this type of science may be one of three kinds. In the first place, it may be an a priori demonstration, and then it consists in proving an effect by its cause. But in this case it is always a question of the remote and common cause. Secondly, it may be an a posteriori demonstration, which proves the cause by the effect; and this maybe either inductive such as is found in the study of nature, or deductive, such as is found in natural theology in the demonstration of God's existence. The last type of demonstratio quia is known as demonstratio a simultaneo; it is used in the demonstration of the existence of a thing by the existence of its corelative or of something that is distinct from it only by a distinctio rationis ratiocinantis.

Since we are dealing with the study of nature, we are interested in the type of scientia quia that arises from inductive a posteriori reasoning. But lest confusion arise, it must be pointed out that in mathematical physics, it is not the whole of physics (in the Aristotelian sense) that is subalternated to mathematics. The first part of natural doctrine that is known as philosophy of nature does not enter into subalternation. It can reduce its demonstrations to its own self-evident principles. It uses induction, to be sure, but a type of induction that arrives at analytic and not merely synthetic propositions. It is, therefore, a deductive as well as an inductive science. It is a scientia propter quid.

It is only the dialectical prolongation of philosophy of nature, known as experimental science, that is subalternated to mathematics. This part of natural doctrine uses a type of induction that arrives only at synthetic propositions. There result from this two important things to be noted about experimental science. First, it pertains to the type of knowledge known as scientia quia. It cannot arrive at a proper propter quid. The best it can do is to construct an imitation, a substitute propter quid by means of hypothesis. Secondly, it is not even a scientia quia

in the strict sense of the word, for it does not give certain knowledge, but only probability.

Now in these two characteristics we find two reasons why experimental science inevitably reaches out to mathematics. For science is certain knowledge of things in their causes.(31) And in order to have science in the full and perfect sense of the word, these causes must be the proper causes. That is why scientia quia is related to scientia propter quid, as an imperfect state of science to a perfect state. That is why all scientia quia aspires to scientia propter quid. Now experimental science is neither certain knowledge, nor is it knowledge of things in their proper causes. Hence it has a double reason for reaching out to a scientia propter quid, i.e. mathematics, in order to obtain for itself at least a substitute certitude and a substitute propter quid. That is why the subalternation of physics to mathematics is not an historical accident. It is the result of a necessary and inevitable scientific tendency. In this connection John of St. Thomas writes:

> In illis scientiis subalternatis ipsi mathematicae, quae usque ad sensibilia excurrunt, pertinet scire scientia quia eo quod res sensibiles per inductionem attingant et usque ad experientiam descendunt. Si autem illa eadem, quae per experientiam cognoscunt, velint scire propter quid, necessario debent uti principiis traditis a mathematica seu a scientia subalternante. (32)

In subsequent discussions we shall adduce fuller evidence to bring out the necessity of the subalternation of physics to mathematics, but perhaps enough has already been said to show how erroneous is the opinion of those modern scholastics who hold that the grounding of physics on mathematics is a great and fatal historical mistake.(33)

As John of St. Thomas points out,(34) when we say that the subalternating science of mathematics knows the cause, or the propter quid of the natural phenomena, this does not mean that it pertains to the subalternating science to know the conclusions of the subalternated science and to demonstrate them. This would mean that mathematics would descend to sensible matter, and in order to do this it would have to abandon its proper abstraction, and thus cease to be mathematics. The expression merely means, as Cajetan explains(35) that the subalternating science knows the propter quid in an abstract and general way, and it is the subalternated science which takes the general principles that are given to it and applies them to its own particular subject matter. This is what Aristotle and St. Thomas have in mind when they point out that the one who knows the reason does not have to know the fact.(36) It should be obvious from what has been said that when Aristotle and

St. Thomas say that the subalternated science knows only the quia, or the fact, this means by itself, independently of the subalternation to the higher science from which it receives its principles. For, by virtue of its subalternation the subalternated science is able to know the cause as well as the fact.

Just as it is possible to have subalternation in the strict sense of the word without the two sciences being related to each other in such a way that the one knows only the fact and the other the reason for the fact, so it is possible to have sciences related in this way without being subalternated to each other. Aristotle gives a simple example of this taken from the science of medicine.(37) A physician may learn from experience that circular wounds heal more slowly than other kinds of wounds; but it is geometry which gives the reason for this: the absence of angles. This, however, does not mean that medicine is subalternated to geometry.

Now St. Thomas makes it very clear that in mathematical physics we really apply abstract mathematical entities to the phenomena of nature.

Perspectiva applicat ad lineam visualem ea quae

demonstrantur a geometria circa lineam abstractam; et harmonica, idest musica, applicat ad sonos ea quae arithmeticus considerat circa proportiones numerorum... Perspectiva accipit lineam abstractam secundum quod est in consideratione mathematici, et applicat eam ad materiam sensibilem (58)

When a physicist speaks of light being propagated in a straight line his calculation proceeds from mathematical straightness. Of course, he is not properly concerned with the mathematical line, but with the physical line which connotes the mathematical line that is applied to it. It is extremely important to keep in mind that it is actually the abstract mathematical entity that is applied to nature.

This application is not merely the reverse of mathematical abstraction. It does not consist merely in fitting back into sensible matter what was lifted out of it by the second degree of formal abstraction. For, as we shall see in Chapter VI, the abstraction that is found in mathematics is different from that found in all the other sciences in this that we cannot go back to reality from the abstract notions and find them realized there. There is a world of difference between the abstract notion of man and the abstract notion of straight line. In the first case, we can find the notion of man realized in the concrete. In the second case, although we can find a line in nature, we cannot find a

perfectly straight line.

Although we cannot pass from the world of mathematics to the world of physical reality by a process of direct concretion, which would simply be the reverse of abstraction, we can do so by a process of extrinsic application. The fact that this is merely an application and not a direct realization shows that the mathematical interpretation of nature is necessarily a scientia media. It also shows that the propter quid which mathematics supplies to the study of nature always remains in some sense extrinsic to nature. This would be true even in the hypothetical case mentioned earlier in this Chapter in which a superior intelligence would find it possible to treat natural phenomena in terms of mathematics in a strictly scientific way.

For us the mathematical propter quid must also remain extrinsic to nature in the sense of its being dialectical. The inadequacy of all our measurements and the limitation of all our experience both with regard to space and time makes it necessary for us to operate within an extremely restricted frame where no phenomena can be sufficiently accounted for. Given this inadequacy of our

measurements and experiments and the uncertainity of our reasoning, the application of a mathematical proposition to a natural subject must be considered as something essentially tentative. The mind ever goes beyond the data of experience in this application, and in so far as this application inevitably outreaches what is conveyed to us by experience, the mind is out on its own, so to speak. As a consequence, the subject formally attained is never wholly divorced from the part played by reason itself. And to the extent in which there is in the subject something coming from reason alone, the subject itself must be called a dialectical entity.

It is clear, therefore, that in mathematical physics we can never arrive at anything more than a provisional and substitute propter quid. This is attested to by the history of physics. In Newtonian physics, for example, the propter quid for many natural phenomena was found in Euclidian geometry; in Einsteinian physics the propter quid for the same phenomena is found in non-Euclidian geometry.

As we have seen, physics reaches up to mathematics in an attempt to escape the dialectical status imposed upon

it by its lack of true universal necessity. But it is clear from what has just been said that, because mathematics cannot provide an explanation that will give universal necessity for the meaning of nature, physics does not succeed in escaping from its dialectical status by becoming subalternated to mathematics. In fact, it becomes doubly dialectical.

But for the present the important point is that physics, because of the opacity of the universe of matter, is forced to go out into a new world to find light, and having found it in the world of mathematics, it brings it back into the material world. As Cassirer has remarked, "that form of knowledge, whose task is to describe the real and lay bare its finest threads, begins by turning aside from this very reality and substituting for it the symbols of number and magnitude."(39) It is a strange light that we bring back from our excursion into the world of mathematics, for as we shall see, mathematical abstraction is in one sense richer and in another sense poorer than any other type of scientific abstraction. In this connection it is important to note the exact formality of the expressions used by St. Thomas in his discussion of

the application of mathematics to physics: "Hujusmodi scientiae utuntur speciebus idest formalibus principiis, quae accipiunt a mathematicis." This shows that the mathematical forms in physics are something essentially alien to the physical world, and that the role played by mathematics is from this point of view purely instrumental.

In mathematical physics, then, we take a mathematical line, for example, and apply it to the physical line. In other words we consider the latter as if it were a straight line. Mathematical physics is essentially a science of als ob. The line which we introduce into nature is the fruit of our own abstraction, and cannot exist as such in reality. We have here a kind of application of a priori forms, and consequently a kind of a priori knowledge. And once again it becomes evident how much Kantianism there is in mathematical physics.

In connection with this insistence that what is applied to nature is actually the abstract mathematical entity, we must consider for a moment a possible interpretation of mathematical physics which at first glance appears highly plausible, but which is fundamentally erroneous. We refer to an interpretation which would consider the so-called mathematical entities merely idealizations or limit

cases of physical entities. Experimental science deals constantly with idealizations and limit cases. When a physicist speaks of the laws of gases he has in mind a "perfect gas" which exists nowhere in nature. Does it not seem plausible that when he speaks of a "perfectly straight line" he is likewise speaking merely of an idealization of a sensible line, that is to say, a sensible line pushed to its limit case? If this interpretation were correct, mathematical physics would not be a scientia media, for just as the introduction of such idealizations and limit cases as "perfect gas", does not involve the application of a superior science, so neither would the idealization of a sensible line. This would bring us back to something similar to the doctrine of Professor Mansion discussed in the last chapter.

Such an interpretation cannot be admitted. Idealizations and limit cases are not the product of formal abstraction, but merely of negative abstraction. It is possible, of course, to push certain physical entities to their limit case and thus arrive at something which superficially resembles mathematical entities. It is likewise possible to attempt to study nature in terms of these idealizations. However necessary negative abstraction of this kind may be, it remains something common, and does not account for the peculiar intelligibility provided by the application of the

positive abstraction of mathematics. The great rational elaborations of mathematical physics show that it is a specifically superior source of intelligibility that has been introduced into nature which of itself is less rational.

It is true that the basic relations between variable quantities out of the mathematical physics is constructed are given implicitly in a concrete quantitative determinations of nature. But it is illegitimate to conclude from this, as Professor Renoirte seems to have done, that there is no subalternation of a lower to a higher science involved.(40) For mathematical physics is not a mere collection of concrete quantitative relations or of concrete measure-numbers. It is essentially a mathematical elaboration and interpretation of these initial data. And it is in this elaboration and interpretation that the subalternation consists.

After explaining that the subalternation of physics to mathematics consists in this that the former gets its propter quid, its cause and reason from the latter, Aristotle and St. Thomas go on to explain the particular nature of this cause.(41) Now the only propter quid which mathematics can give to the study of nature must be in the line of formal causality. For of all the four causes the

only type of cause that is found in mathematics is the formal cause. The mathematical world is a completely immobile world. In it there is no becoming and hence no subject, no agent, no purpose. It is a world of pure forms. And this gives us an insight into the peculiar nature of mathematical physics. If it were purely physics it would try to resolve things in terms of all the four causes. But because it is formally mathematical it causes things only in the light of formal causality. This is an extremely important point, and we shall return to develop it later. For the moment let it suffice to bear in mind that the cause which mathematics contributes to physics is in the general line of formal causality, and pertains in particular to the structural order.

Now since mathematical physics is an intermediary science between physics and mathematics, it is necessary to try to determine to what extent it participates in both of these sciences. Does it participate in both of them in equal measure, so to speak, or does none of the two predominate over the other? From what has been said up to this point one might easily be led to deduce conflicting answers to this question. For in discussing the structure of a mixed

science we stated that an accidental element taken from the object of the lower science is added to the object of the higher science. From this it would seem to follow that the most important element in the object of mathematical physics is the element taken from mathematics, and that the physical element is merely an accidental addition to it. On the other hand, when the question arose about the kind of unity found in the object of an intermediary science we said that the object which mathematical physics considers directly and per se is the physical element, and the mathematical element is brought into the consideration in a kind of oblique fashion by way of connotation.

If we look for the solution of this antinomy in the writings of Aristotle and St. Thomas, our difficulty is aggravated. For on the one hand, Aristotle seems to class the physico-mathematical sciences among the mathematical sciences.(42) Moreover, we read in Saint Thomas that these sciences are "magis affines mathematicis, quia in eorum consideratione id quod est physici, est quasi naturale; quod autem mathematici, quasi formale."(43) And John of St. Thomas says: "Cantrologus non agit de coelo et planetis, ut sunt entia mobilia, sed ut mensurabiles sunt eorum motus et secundum varios aspectus diversam

proportionem induunt, quod magis pertinet ad mathematicum quam ad physicum."(44) On the other hand we are told by St. Thomas that these sciences are more physical than mathematical: "Huiusmodi autem scientiae, licet sint mediae inter scientiam naturalem et mathematicam, tamen dicuntur hic a Philosopho esse magis naturales quam mathematicae, quia unumquodque denominatur et speciem habet a termino: unde, quia harum scientiarum consideratio terminatur ad materiam naturalem, licet per principia mathematica procedant, magis sunt naturales quam mathematicae."(45)

There is a text in the Summa which, together with the commentary of Cajetan, throws light upon this apparent paradox:

> Quilibet habitus formaliter quidem respicit medium, per quod aliquid cognoscitur; materialiter autem id, quod per medium cognoscitur; et quia id quod est formale, potius est, ideo illae scientiae quae ex principiis mathematicis concludunt circa materiam naturalem, magis cum mathematicis connumerantur, utpote eis similiores, licet quantum ad materiam magis conveniant cum naturali; et propter hoc dicitur in II Phys. quod sunt magis naturales.(46)

To this text Cajetan adds the following remarks:

> In responsione ad tertium secundi articuli non dicitur quod scientiae mediae sunt magis mathematicae quam naturales: cum falsum sit, absolute loquendo· quia simpliciter sunt scientiae naturales, utpote non abstrahentes a materia sensibili; omnis enim scientia non abstrahens a materia sensibili est naturalis, ut patet VI Met. Sed dicitur quod

connumerantur magis cum mathematicis, utpote eis similiores. Et de connumeratione quidem liquet, quia cum geometria et arithmetica scientiae numerantur inter liberales artes. De similitudine autem in modo demonstrandi manifestum est, dum mensurando et quantificando conclusiones monstrantur. Verum quia medium utrumque sapit extremum; et scientiae istae ex parte formae ex mathematica veniunt et pendent, ex parte materiae physicae sunt: sermones Doctorum pie interpretandi sunt, si quando ad alterum extremum nimis declinant.

Perhaps a more sharply drawn distinction will serve to dispel all confusion on this point. From the point of view of its ratio formalis quae, mathematical physics is more physical than mathematical; from the point of view of its ratio formalis sub qua, it is more mathematical than physical. The ratio formalis quae is the physical considered as connoting the mathematical and as determined and modified by it. Consequently the physical is considered directly, whereas the mathematical is brought in only indirectly and obliquely. The terminus or end of mathematical physics is the knowledge of nature. It is not the knowledge of the mathematical world that the mathematical physicist is striving for (that is already presupposed) but of the physical world. As we saw in Chapter II, mathematics does not terminate in sense experience, and the origin which it has in sense experience is only remote and pre-scientific. Mathematical

physics, on the other hand, both originates and terminates in sense experience, even though, due to the role played by mathematics, there are introduced between the origin and the terminus many elements which have no counterparts in sense experience. All this explains why we speak of mathematical physics and not of physical mathematics. And from this point of view, physico-mathematical science may be numbered among the physical sciences. As Cajetan points out in the passage just cited, mathematical physics does not abstract from sensible matter, and judged by this criterion it may be said to be a natural science.

Yet it would be erroneous to conclude that physico-mathematical science is formally identified with pure natural science. As a matter of fact, it is distinguished from it specifically both by its ratio formalis quae and its ratio formalis sub qua. For in so far as the ratio formalis quae is concerned, we have just seen that, while the physical is considered directly and primarily, it is nevertheless, considered only as connoting the mathematical and as modified by it. Now this connotation and modification introduces a profound change. As we pointed out in the last Chapter, the ratio formalis quae of all pure natural science is mobility. This, however, cannot be said

to be the ratio formalis quae of mathematical physics, for as we shall explain later on, the introduction of mathematics into physics destroys all true mobility by the very fact that there is no true becoming intrinsic to mathematics. Movement undoubtedly plays a large part in mathematical physics, but it is movement in the Cartesian sense, which is a state and a relation, and not a process or a becoming. Mathematical physics does not study the physical world as mobile, but as measurable. As John of St. Thomas says in a text already quoted, "Astrologus non agit de coelo et planetis ut sunt entia mobilia, sed ut mensurabiles sunt eorum motus et secundum varios aspectus diversam proportionem induunt, quod magis pertinet ad mathematicum quam ad physicum." (47) Yet mathematical physics does not dispense completely with mobility. For there is an essential relation between its formal object and that of pure natural science. The extremely paradoxical character of mathematical physics has already been noted: in order to draw closer to the absolute world condition it draws away from it by going out into another world, that of mathematics. Applying this to the point under discussion, we may say that in order to understand the mobility of the cosmos it prescinds from it by introducing mathematics. But the important point is that in prescinding

from it, it is tending towards a more perfect understanding of it. The limit of this tendency would be an identification of the formal object of mathematical physics with that of pure natural science. Even though this limit can never be reached, nevertheless there is in the state of tendency an essential relation between the two formal objects.

In mathematical physics there is a triple dialectical movement. First, there is the movement from the state of generality towards the ultimate concretion. Secondly, there is the movement from the state of probability towards the state of certitude. Both of these dialectical movements are common to all experimental science. And thirdly, there is the movement proper to mathematical physics - the one we have just explained. All of these three movements are intimately bound together.

Physico-mathematical science is distinguished from pure natural science not only by its ratio formalis quae, but also by its ratio formalis sub qua. In fact, from the point of view of this latter ratio it is closer to mathematics than to physics, just as from the point of view of the former it is closer to physics than to mathematics. Mathematical physics is formally mathematical. It gets its propter quid from mathematics, and since the propter quid

gives the reason and cause of the natural phenomena, it stands in relation to the latter as form to matter. All this means that mathematical physics proceeds under the light of mathematical evidence. This would seem to imply that the special type of abstraction which constitutes its ratio formalis sub qua, and which, as we saw above, stands in between mathematical and physical abstraction and shares in the character of both, is more mathematical than physical. Though principally mathematical it is not, however, specifically mathematical, since it is applied to a physical object in order to constitute a new subject and new principles proper to a science concerned with physical reality. In other words, though mathematical physics is formally mathematical, it is not specifically mathematical.

From what has just been said about the parts played by mathematics and physics, it should be clear that when we say that mathematical physics is formally mathematical and materially physical this does not mean that the formal object is mathematical and the material object is physical. For the objectum formale quod has to do with the physical world. Some modern scholastics seem to be confused on this point.(48) It should also be clear how completely Aristotle is misrepresented by Professor Mansion

when he writes:

> On voit donc comment, en écartant de la physique, pour les assigner au domaine mathématique les sciences mentionnées à l'instant, Aristote a manqué l'occasion de traiter à fond sur des cas concrets parfaitement adaptés, le problème de la différence entre une étude philosophique et une étude purement scientifique de telle ou telle portion du monde matériel. (49)

Aristotle in no way removed the physico-mathematical sciences from the realm of physics. If he listed them among the mathematical sciences it was merely because they are formally mathematical. And he took pains to point out explicitly that while they are closer to mathematics from this point of view, they are at the same time more natural than mathematical. In his mind they were, of course, specifically distinct from pure natural science, but this did not remove them from the realm of physics, since their whole raison d'être was to get to know the physical universe.

At this point it is interesting to compare what has been said thus far about the nature of mathematical physics as a scientia media, formally mathematical and materially physical, with two passages from Albert Einstein, one of which has already been quoted. There is a remarkably close affinity between what the ancient Thomists taught about mathematical physics as formally mathematical and what

Einstein has to say in the following lines:

> It is my conviction that pure mathematical construction enables us to discover the concepts and laws connecting them which give us the key to the understanding of the phenomena of Nature. Experience can of course guide us in our choice of serviceable mathematical concepts; it cannot possibly be the source from which they are derived; experience of course remains the sole criterion of the serviceability of a mathematical construction for physics, but the truly creative principle resides in mathematics.(50)

In the same way, the following passage seems an exact confirmation of the Thomistic doctrine that mathematical physics is materially physical:

> Pure logical thought cannot give us any knowledge concerning the world of experience; all knowledge of reality begins in experience and ends in experience. The conclusions obtained by means of purely rational processes are, in so far as reality is concerned, entirely empty.(51)

We are now in a position to understand with greater exactness a point to which some attention was given in Chapter I. We refer to the question of whether or not the role of mathematics in mathematical physics is purely instrumental. It should be evident from what has been said that it cannot be purely instrumental in the sense of being a mere logical tool or a convenient language. For neither a logical tool nor a language enters into the very object of the science that employs them. They remain essentially extrinsic to that object. But in mathematical physics, an

element of mathematics enters into combination with a physical element to constitute the very object which specifies that science. And yet because it does not enter into it directly, but in an oblique fashion by way of connotation, and because as a consequence the objectum formale quod, that is, the thing that mathematical physics is trying to get to know, the thing that is the terminus and the end of the whole science, is something of the physical world, and not the mathematical world, we may say that in this sense the role of mathematics is purely functional. Mathematics is employed in physics only as a means to get to know the physical universe. As Professor Babin has pointed out, the physicist who loses sight of this purely functional character cannot fail to pervert his science:

> Parce que la fin du savoir physico-mathématique est tout de même la nature sensible, le physicien mathématicien, à tendance mathématisante, pervertit sa science, quand il se désintéresse des choses naturelles elles-mêmes pour se complaire, comme dans un terme, dans l'ordre et la beauté de son objet formel, donc dans l'aggregatum ut sic, en tant que celui-ci est un composé accidentel et oeuvre de sa raison, et pure substitut de la nature. C'est un artiste égaré ou frustré, et qui se sert de la nature comme d'une matière ouvrable. Ou raisonne, il feint en fin ce qui est moyen seulement, et préfère contempler l'oeuvre de sa raison plutôt que la nature, qui est l'oeuvre de l'intelligence divine.(52)

Emile Meyerson makes the following commentary on the pivotal text of the Posterior Analytics in which Aristotle explains his conception of mathematical physics as an intermediary science:

> Il y a évidemment, dans ce dernier morceau une sorte de tendance parmathématique, laquelle n'a pas manqué d'embarrasser quelque peu les commentateurs dont certains même ont cru pouvoir observer que le Stagirite, transgressant les règles qu'il avait posées ailleurs, paraissait bien passer ici d'un genre à un autre.(Note: Cf. notamment la note de Barthélemy-St.Hilaire, Logique d'Aristote, t.III, Paris, 1842, p.85). Mais si l'on fait abstraction de ces passages, qui semblent plutôt un héritage provenant des philosophes de l'Académie, la pensée d'Aristote s'avère parfaitement orientée dans le même sens que celle de Bosanquet, tout en étant en quelque sorte plus extrême que celle-ci.(55)

It is extremely difficult to find any trace of a tendency towards parmathematicism in Aristotle's doctrine of mathematical physics. He never identified mathematics with physics. On the contrary, through his doctrine of subalternation, he kept them both distinct, while at the same time recognizing their intimate relation. He never held that the whole of physics could be subalternated to mathematics, to say nothing of the other sciences. Much less did he ever attempt to erect the mathematical interpretation of reality into a metaphysics. Nor have any of his great commentators -- those who have understood him

doctrine most correctly and given it most genuine and integral development -- ever manifested the slightest embarrassment over this text from the Posterior Analytics. On the contrary, they have considered it to be in perfect harmony with all of the epistemological principles of the Aristotelian synthesis.

There is no difficulty in admitting an influence of the Academy upon this particular point of Aristotle's doctrine. Aristotle himself would certainly be the last one to deny his great indebtedness to Plato. But it is not, as Meyerson suggests, a heterogeneous bit of doctrine that was accepted by a kind of strange concession to ecclecticism. Rather it is something that has been purified of Platonist exaggerations and brought into perfect line with the whole body of Aristotelian epistemology. As for the charge that this text represents a transgression of rules laid down by Aristotle elsewhere — we have already considered this point both in this Chapter and in the last part of Chapter II, and there is no need of reconsidering it here.

These remarks conclude our explanation of the basic principles underlying the Thomistic philosophy of

mathematical physics. The chapters which are to follow will be an elaboration of these. As we have seen, there are two pivotal points around which these principles revolve: the nature of the distinction between physics and mathematics, and the nature of scientia media. The next three chapters will be a development of the first point, and the remaining Chapters a development of the second. The next two Chapters will be devoted to an analysis of the science of nature, and the one following them to an analysis of the science of mathematics. The study of scientia media will fall naturally in two parts: first we shall consider the way in which this intermediary science is constituted (Chapters VIII and IX), and secondly we shall analyse the nature of the physico-mathematical world which results from this mediation (Chapters X to XIII).

manifest itself with greater brilliance than by the order

CHAPTER FOUR

COSMOS AND LOGOS

1. Movement Towards Concretion.

At the beginning of his Commentary on the De Coelo et Mundo, St. Thomas has this to say:

> ... Philosophus ostendit in scientiis esse processum ordinatum, prout proceditur a primis causis et principiis usque ad proximas causas, quae sunt elementa constituentia essentiam rei. Et hoc est rationabile: nam processus scientiarum est opus rationis, cuius proprium est ordinare; unde in omni opere rationis ordo aliquis invenitur, secundum quem proceditur ab uno in aliud. Et hoc patet tam in ratione practica, cuius consideratio est circa ea quae nos facimus, quam in ratione speculativa, cuius consideratio est circa ea quae sunt aliunde facta.(1)

It is proverbial that the most characteristic property of wisdom is order: sapientis est ordinare.(2) And perhaps in no way does the profound wisdom of Aristotle and St. Thomas manifest itself with greater brilliance than by the order that is found in their writings. This order is sometimes left to impose itself upon the mind by its own clarity without explicit attention being called to it. At other

times, when there is special need of insisting upon the right order to be followed, an effort is made to explain and justify the order adopted. And nowhere in their writings do Aristotle and St. Thomas lay such particular stress upon the question of order as in their treatises on natural doctrine. It is the first problem discussed at the beginning of the eight books of the Physics, and time after time throughout the subsequent treatises it is brought back into focus, and the basic principles involved in it are reconsidered.(3) As we shall presently attempt to make clear, the history of philosophy, and the history of modern thought in particular, have shown that this emphatic insistence upon the correct order to be followed in the study of nature was far from being gratuitous.

But if this question is to be put into proper perspective, we must begin by recalling that there are two issues involved in the general problem of scientific order. First, there is the question of the right ordering of the different sciences among themselves, and this has been treated at some length in Chapter II. Secondly, there is the question of the right ordering of the different parts of the same science; this has been touched upon lightly in Chapter II, but we must now consider it in greater detail

in so far as it involves the study of nature.

St. Thomas brings out this double movement of the scientific mind in his Commentary on the De Sensu et Sensato:(4)

> Et sicut diversa genera scientiarum distinguuntur secundum hoc quod res sunt diversimode a materia separabiles, ita etiam in singulis scientiis, et praecipue in scientia naturali, distinguuntur partes scientiae secundum diversum separationis et concretionis modum. Et quia universalia sunt magis a materia separata, ideo in scientia naturali ab universalibus ad minus universalia proceditur.

In other words, both the ordering of the different sciences and the ordering of the parts of the same science are determined by different degrees of mental separation, but in each case a distinct type of separation is involved. In the case of the ordering of the various sciences it is a question of a separation from materiality according to different levels of formal abstraction, and the natural movement of the mind is from the less abstract to the more abstract. In the case of the ordering of the different parts of the same science, it is a question of a separation from concreteness according to different levels of total abstraction, and the natural movement of the mind is from the more abstract to the less abstract.(5)

It is commonly supposed that progress in science means an increase in abstractness. As a matter of fact, it is just the contrary that is true.(6) This refers, of course, to the sciences whose object is to know existential reality. To get to know concrete reality better means to get to know it with greater concreteness. Mathematics, precisely because it is the science of the abstract qua abstract, can make progress by growing in abstractness, but in the study of nature and in metaphysics the movement must be towards fuller concretion. In metaphysics this movement is from the communia entis up through the realms of the created separated substances to Pure Act. In the study of nature the movement towards concretion carries the mind in some sense in the opposite direction -- into deeper immersion in matter.

Perhaps at first sight all this may seem to be in direct contradiction to the actual historical development of physics. Bertrand Russell has claimed that "in proportion as physics increases the scope and power of its methods, in that same proportion it robs its subject-matter of concreteness."(7) Surely relativity physics and quantum physics are immeasurably more abstract than anything that the past centuries have produced.

It cannot be denied that progress in modern physics has meant an increase in abstractness. But at the same time, it has also meant an increase in concreteness. Atomic physics, for example, in spite of its abstract constructions (or rather precisely because of them -- as we shall explain in a moment) has brought us into more intimate contact with concrete reality than we ever were before. There is nothing paradoxical in this double movement towards concreteness and abstractness. It merely reveals the fact that modern physics is not a pure physical science, but a scientia media in which physics a science of the concrete is subalternated to mathematics, a science of the abstract.(8)

In this Chapter we are concerned with the study of nature in so far as it prescinds from subalternation to mathematics. That is why the movement that must claim our attention in a particular way is the one towards fuller concretion. Moreover, even in mathematical physics, the movement towards abstractness is secondary and purely functional, since its whole purpose is to assist the movement towards concretion. That is why it is of extreme importance to analyze the nature of this latter movement.

In the first Chapter of the first book of the

Physics, Aristotle writes:

> The natural way of doing this is to start from the things which are more knowable and obvious to us and proceed towards those which are clearer and more knowable by nature; for the same things are not 'knowable relatively to us' and 'knowable' without qualification. So in the present inquiry we must follow this method and advance from what is more obscure by nature but clearer to us, towards what is more clear and more knowable by nature. Now what is to us plain and obvious at first is rather confused masses, the elements and principles of which become known to us later by analysis; Thus we must advance from generalities to particulars; for it is a whole that is best known to sense-perception, and a generality is a kind of whole, comprehending many things within it, like parts. (9)

It is clear from this capital text that for Aristotle the basic order to be followed in the study of nature is one which moves from the more confused to the more distinct, from the more universal to the more particular, from the more abstract to the more concrete. But he does not lay down this principle, which is to serve as the guiding light throughout his long researches into nature, without seeking to give it full justification. And St. Thomas, in his commentary on this passage, shows that this justification can be cast in the form of a simple syllogism:

> Innatum est nobis ut procedamus cognoscendo ab iis quae sunt nobis magis nota, in ea quae sunt magis nota naturae; sed ea quae sunt nobis magis nota, sunt confusa, qualia sunt universalia; ergo oportet nos ab universalibus ad singularia procedere.(10)

Each of the propositions in this syllogism deserves attentive examination.

In the first place it is clear that in the pursuit of science we must start with those things which are most knowable for us, and gradually pass on to those things which are less knowable for us. This principle is so obvious that it does not need justification. But it so happens that there is an inverse proportion between the knowability that things have for us and the knowability that they have in se. And we do not have to seek very far to find the reason for this. For, since being and ontological truth are convertible, things are objectively knowable according to the measure of perfection of being which they possess. And since things have perfection of being to the extent in which they are in act, it follows that their objective knowability is determined by their degree of actuality. That is why, if our intellects were in the fullness of actuality, their order of knowing would coincide with the objective order of knowability. But it happens that they are far from possessing the fullness of actuality - - as far as it is possible for any intellect to be. As a matter of fact, they must begin the process of knowledge from noetic pure potency - - a tabula rasa - - and gradually move in the direction of fuller actuality.

And that is why the knowability of things for us is in inverse proportion to the knowability of things in se. In other words, the intellect must acquire knowledge, not in conformity with its act, but in conformity with its potency. If it were to acquire knowledge in conformity with its act, it would suffice for it to exist in order for it to have knowledge in act. Hence the first object of knowledge must be that which is most in conformity with the intellect's state of potentiality. (11)

In our discussion of the nature of abstraction in Chapter II we pointed out that one of the differences between formal and total abstraction emphasized by Cajetan consists in this that as we advance in formal abstraction we are moving from what is more knowable to us and less knowable in se to what is less knowable to us and more knowable in se, while an advance in total abstraction means a movement in the opposite direction. And this explains why in the ordering of the different sciences we must ascend the levels of formal abstraction and advance from the less abstract to the more abstract, whereas in the ordering of the different parts of the same science we must descend the levels of total abstraction and pass from the more abstract to the less abstract. In both cases we are moving from the more knowable

for us towards the more knowable in se, that is to say, from potentiality to actuality. In the first case it is a question of the potentiality of materiality; in the second case it is a question of the logical potentiality of universality.

And this brings us to an explanation of the minor of our syllogism. It is fairly obvious why the mind, if it is to follow its natural movement of passing from potentiality to actuality, must begin with the more general and gradually advance in the direction of the more particular. For universals contain their subjective parts only in a confused and indistinct way, that is to say, in potentiality. In other words, the universal stands in relation to the particular as indetermination to determination, and hence as potency to act.

In connection with the conclusion of the syllogism it is necessary to note that the expression "singularia" does not refer to individuals but to species. We have already brought out this point in our criticism of Maritain in Chapter II. And perhaps it is not superfluous to mention in passing that in this whole discussion Aristotle and St. Thomas are dealing only with intellectual knowledge, for obviously a

knowledge of particulars by the senses is a prerequisite for the formation of universals by the mind.

The terminus, then, towards which the whole study of nature must ever move is ultimate specific concretion. It does not aim to lose itself in the infinite potentiality of individual concretion -- de singulis non est scientia. It must begin with the consideration of mobile being in general and analyze its structure and properties; from there it must move towards the full and adequate determination of the unique mobility that is proper to each natural species. This is a goal that actually transcends the powers of the human mind, as we shall explain more fully a little later; but it provides a limit towards which natural science must ever tend if it is to be true to its own intrinsic nature.

The study of mobile being, therefore, is essentially a science that must ever remain in the state of mobility. For though from one point of view the generalities which constitute the first part of the science of nature are the most satisfying for the mind, since they are the truths that are most knowable for us, and, as we shall presently see, the truths about which we can have the greatest certitude, from another point of view they are

the least satisfying. For, by their very generality and vagueness, they give us only a superficial knowledge of nature; they provide only a kind of introduction to the study -- material reality, in somewhat the same way as the communia entis in metaphysics provide only an introduction to the study of immaterial being. The true student of nature will never be satisfied with the superficiality of this introduction. He will want to come into more intimate contact with cosmic reality. And in order to achieve this, he will never cease his efforts to advance in the direction of fuller concretion. In his commentary on the Libri Meteorologicorum St. Thomas writes:

> Sicut in rebus naturalibus nihil est perfectum dum est in potentia, sed solum tunc simpliciter perfectum est, quando est in ultimo actu; quando vero medio modo se habens fuerit inter puram potentiam et purum actum, tunc est quidem secundum quid perfectum, non tamen simpliciter; sic et circa scientiam accidit. Scientia autem quae habetur de re tantum in universali, non est scientia completa secundum ultimum actum, sed est medio modo se habens inter puram potentiam et ultimum actum. Nam aliquis sciens aliquid in universali, scit quidem aliquid eorum actu quae sunt in propria ratione eius; alia vero sciens in universali non scit actu, sed solum in potentia -- . Unde manifestum est quod complementum scientiae requirit quod non sistatur in communibus, sed procedatur usque ad species.(12)

Aquinas points out elsewhere that natural forms have their very being "in concretione ad materiam."(13) That is why one

can come into intimate contact with them only by delving deeper and deeper into matter.

Perhaps this last point will present a difficulty to the mind. For this delving into the depths of matter may seem to be leading us in the direction of greater objective unintelligibility, whereas we stated a few moments ago that the movement towards concretion means an advance towards things which are more intelligible in se. The solution of this difficulty is fairly simple: even though the things of nature because of their materiality are less intelligible in se than immaterial things, they are, nevertheless more intelligible in se in the state of concretion with matter than in the state of vague generality.

Having established the fact that natural science must move from generality to concretion we must now consider the problem of how this movement is carried out. This is a question of extreme importance, for it has to do with what is perhaps the most widely misunderstood point of the whole Thomistic philosophy of science.

It has become traditional among historians and philosophers of science to insist with great emphasis upon the completely antithetical character of the scientific

spirit of the Renaissance in comparison with the Aristotelianism that had dominated the preceding centuries. We are told (almost invariably without any attempt at proof) that Aristotle and his medieval followers had held that the whole of cosmic reality could be deduced a priori from a few general principles, and that it was only at the time of the Renaissance that the essential role played by experience and induction in the study of nature was first clearly recognized. This condemnation of Aristotelianism is so universal that it is found even among those who have won for themselves considerable repute as historians of science. Emile Meyerson, for example, tells us in more than one place in his writings that, as Malbranche pointed out, Aristotle's natural science was not physics but logic, that it was, in fact, a panlogicism similar to that of Hegel. The following passage from De L'Explication dans les sciences is typical:

> ... elle (la théorie d'Aristote) présente également un essai de déduction globale de la nature. Comment s'opère effectivement cette déduction, par quel moyen a l'aide des concepts de matière et de forme les phénomènes se constituent, c'est ce que les manuels enseignent suffisamment pour que nous puissions nous abstenir de l'exposer ici. Contentons-nous de relever que la déduction domine le système entier. Tout doit se ramener au syllogisme, et Aristote ne connaît de démonstration scientifique que par le syllogisme, cette démonstration, comme l'a justement formulé Zeller, étant chez lui une conclusion résultant de prémisses qui sont elles-mêmes nécessaires. C'est au point que l'on a pu

> dire que la science d'Aristote était, non pas une physique, mais une logique. C'est là en effet, l'impression qu'en reçoit un homme élevé à l'école de la science moderne. Mais il est clair que, pour le maître du péripatéticisme, aussi bien que pour ses sectateurs de l'antiquité et du moyen âge, les deux se confondent puisque la nature ne peut être que logique .... C'est là un état d'esprit qui, sans doute, paraît fort éloigné du nôtre. Il n'est cependant pas impossible de lui trouver un parallèle à une époque très rapprochée de nous. Hegel, nous le verrons plus tard, a entrepris une tâche sinon identique à celle que se proposaient les Ioniens ou Aristote, du moins fort semblable, en ce sens que, tout en ne prétendant pas déduire la nature entière, il croyait cependant pouvoir recréer, par sa métaphysique, tout ce qu'il y avait en elle d'essentiel. (14)

Later in the same work Meyerson claims that Peripateticism was an even more extreme form of panlogicism than Hegelianism, since Hegel did not hold that the whole of natural science was deducible whereas Aristotle did. And he finds a reason for this difference in the fact that the great advances made in experimental science between the time of Aristotle and that of Hegel could not help but influence the latter, in spite of his "arrogance logique." (15) Levelled against the decadent Scholastics of the late middle ages, or against the modern writers of Scholastic manuals (to which, incidentally, Meyerson seems to have gone to find his "déduction globale") this accusation has some justification. But applied to Aristotle and St. Thomas it is nothing short of sheer calumny. We do not hesitate to

say that no system of philosophy is so diametrically opposed to Peripateticism as Hegelianism.

In the first place, it is extremely interesting and significant to note that in his commentary on the opening passages of the Physics which we have been trying to analyse, St. Thomas explicitly excludes the interpretation of Aristotle which has become current among modern historians and philosophers of science. This interpretation had already been proposed as far back as the time of Averroes. According to Averroes, when Aristotle speaks of the movement from generalities to particularities he has in mind a process of deduction or demonstration whereby the latter are drawn from the former, in which they are already precontained as parts in a composite whole. St. Thomas' refutation of this interpretation is precise and to the point:

> Sciendum autem quod Commentator aliter exponit. Dicit enim quod ibi, Innata autem est etc., vult ostendere Philosophus modum demonstrationis huius scientiae, quia scilicet demonstrat per effectus et posteriora secundum naturam: ut sic quod ibi dicitur, intelligatur de processu in demonstrando, et non de doctrinando. Cum autem dicit, Sunt autem nobis etc., intendit manifestare, secundum eum, quae sunt magis nota quoad nos et minus nota secundum naturam, scilicet composita simplicibus, intelligens composita per confusa. Ultimo autem concludit quod procedendum est ab universalioribus ad minus universalia, quasi quoddam corollarium. Unde patet quod eius expositio non est conveniens,

> quia non coniungit totum ad unam intentionem; et quia hic non intendit Philosophus ostendere modum demonstrationis huius scientiae, hoc enim faciet in secundo libro secundum ordinem determinandi: iterum quia confusa non debent exponi composita, sed indistincta; non enim posset concludi aliquid ex universalibus, cum genera non componantur ex speciebus. (16)

The last lines of this passage which we have italicized are extremely important. They show that for St. Thomas absolutely nothing can be deduced from the generalities with which the study of nature begins. But in order to come to understand this point as clearly as possible, it is necessary to analyze the nature of the universality that is found in the first part of natural doctrine.

According to St. Thomas (17) there are two kinds of universality -- universality by predication and universality by causality. As the name implies, universality by predication arises from the possibility which a universal notion has of being predicated of a number of inferiors. It consists, therefore, in pure generality, and as a consequence, the greater universality of this type a notion possesses, the emptier, the more confused, the more indetermined it is. Because of this indetermination, notions and principles which have more universality of predication cannot be sources of deduction; their emptiness renders

them barren. Universality of causality, on the other hand, arises from the capacity of producing a number of effects. Increase in universality of this kind means an increase in richness and fullness of being; it means an increase in fecundity, since the effects actually derive from the principle which possesses this universality as from a source.

The notion which possesses the greatest universality of predication is obviously the general and confused notion of being. On the other hand, the principle which possesses the greatest universality of causality is the Subsistent Being, or God. That is why no greater error could be made than to confuse these two kinds of universality. And in this connection Professor Dehoninek writes:

> Il me semble que l'idéalisme de Hegel est la philosophie la plus universellement opposée à la nôtre. Cet idéalisme nous est plus distant que le matérialisme; il est, à parler absolument, plus matérialiste que le matérialisme; il accorde, en effet, au premier connu, à l'être prédicat le plus universel, le plus confus, le plus indéterminé, le plus pauvre, le plus inévident en soi, la place qui, dans notre philosophie, revient à Dieu. La position de Hegel est dès lors inférieure, même à celle de David de Dinant, 'qui stultissime posuit Deum esse materiam primam'. (In, q. 3, a. 8, c.) Car son principe en soi premier a plus raison de matière que la matière physique.(18)

Now the generalities with which the study of nature begins possess only universality of predication.

From this point of view they are the emptiest, the most indetermined, the most confused, the most superficial of all the truths that can be learned about the cosmos. That is why they cannot be sources of deduction.

There are some scientific first principles which have not only universality of predication, but at the same time something which may be compared with universality of causality. These are found in mathematics, and that is why from a few primary axioms and postulates a whole geometry can be rigorously deduced. There is a world of difference between the principles from which mathematics takes its start and the generalities which constitute the beginning of the science of nature. Mathematics can progress by sheer deduction; the science of nature cannot. Yet deduction is something for which the mind instinctively reaches out, since through it man can become prior to things and in some sense the cause of them. And that is one of the reasons why it is inevitable for the science of nature to be subalternated to mathematics so that nature may be transformed to some extent at least into a deductive system.

But for the moment we are interested only in the way in which the study of nature advances from generalities

to fuller concretion. Enough has been said to show that this cannot be accomplished by means of deduction. That leaves us with only one alternative: experience and induction. It is important to come to see that the potentiality native to the intellect not only demands that we begin with generalities, but also that in attempting to escape from these generalities we take every step in complete dependence upon the data of experience. And thus we are brought to a consideration of the part that induction and experience play in the Thomistic philosophy of science. This consideration will serve to clear up not only the historical misunderstanding mentioned above, but also another misunderstanding closely associated with it: the often reiterated accusation that the generalities with which Aristotle and St. Thomas proposed to begin the study of nature were nothing but abortive and ill-founded hypotheses. (19)

2. Thomism and Experience.

We know of no better way of introducing this question than by quoting a text of Aristotle which the historians of science have consistently ignored:

Of things constituted by nature some are ungenerated, imperishable, and eternal, while others are subject to generation and decay. The former are excellent beyond compare and divine, but less accessible to knowledge. The evidence that might throw light on them, and on the problems which we long to solve respecting them, is furnished but scantily by sensation; whereas respecting perishable plants and animals we have abundant information, living as we do in their midst, and ample data may be collected concerning all their various kinds, if only we are willing to take sufficient pains . . . Having already treated of the celestial world, as far as our conjectures could reach, we proceed to treat of animals, without omitting, to the best of our ability, any member of the kingdom, however ignoble. For if some have no graces to charm the sense, yet even these, by disclosing to intellectual perception the artistic spirit that designed them, give immense pleasure to all who can trace links of causation, and are inclined to philosophy. Indeed it would be strange if mimic representations of them were attractive, because they disclose the mimetic skill of the painter or sculptor, and the original realities themselves were not more interesting, to those at any rate who have eyes to discern the reasons that determined their formation. We therefore must not recoil with childish aversion from the examination of the humbler animals. Every realm of nature is marvellous: and as Heraclitus, when the strangers who came to visit him found him warming himself at the furnace in the kitchen and hesitated to go in, is reported to have bidden them not to be afraid to enter, as even in that kitchen divinities were present, so we should venture on the study of every kind of animal without distaste; for each and all will reveal to us something natural and something beautiful. . If any person thinks the examination of the rest of the animal kingdom an unworthy task, he must hold in like dis-esteem the study of man. For no one can look at the primordia of the human frame - - blood, flesh, bones, vessels, and the like - - without much repugnance.(20)

We feel that this text brings into clear light the spirit of research and the respect for concrete facts which animated Aristotle's study of nature. Nor must it be looked upon as an exceptional and isolated passage that demands some ingenuity in order to be reconciled with the actual practice and the epistemological principles of the Stagirite. For other texts of like character could easily be adduced, as for example the one found in the first book of De Generation et Corruptione, where he points out that the main obstacle to the study of nature is insufficiency of experience and that only those who live in great intimacy with natural phenomena can succeed in such a study.(21) As far as actual practice is concerned, one has only to read the natural treatises that are far advanced in the direction of concretion, as for example, the Historia Animalium and the De Partibus Animalium, to see to what extremes he pushed the experimental method. It is said that Alexander the Great had thousands of men engaged in research in every part of the world that was then known in order to assist Aristotle in the writing of his Historia Animalium.(22) It is true that most of this experimental research is restricted to the field of biology, but sufficient reasons have already been brought forward in

Chapter I to explain why this is so.

But the most important point in this discussion is to show that this experimental method follows logically and inevitably from Peripatetic epistemological principles. And in order to do this we must return to what we saw in Chapter II about the intrinsic nature of physical science.

In discussing the distinction of the sciences we explained that natural doctrine differs from all the other sciences by the fact that it does not abstract from sensible matter, and that as a consequence all of its definitions must be formulated in terms of sensible matter. Propositions which prescind from sensible matter can have nothing more than a dialectical meaning in physics. We pointed out that St. Thomas drew from this the principle that unlike mathematics and metaphysics, physics must not only begin in sense experience, it must also terminate in it. Scientific conclusions have no meaning in natural doctrine unless they are verifiable in sense experience. And that is why A uinas could write: "qui sensum negligit in naturalibus incidit in errorem. Et haec sunt naturalia quae sunt concreta cum materia sensibili." (23) It is only experience that can provide us with natural definitions.

All this evidently ties up with the Peripatetic doctrine of hylemorphism. Natural forms, which are the object of natural science, have their very being "in concretione ad materiam." And this refers not merely to their existence, but to their very essence. It is extremely important to keep in mind that a material form is not a quiddity. It is not knowable in itself and by itself independently of matter - - just as matter is not knowable independently of form. Even God does not know material forms except in relation to matter, since independently of matter a natural form is nothing. As a consequence, the perfection of our knowledge of these forms depends upon the intimacy of our contact with sensible matter. And that is why every true Thomist will unhesitatingly subscribe to the principle formulated by Eddington: "Every item of physical knowledge must therefore be an assertion of what has been or would be the result of carrying out a specified observational procedure." (24)

There are many reasons why the whole study of nature is completely dependent upon experience, but in some respects the most profound reason is the one hinted at by Aristotle in the passage quoted above from the De Partibus Animalium: the material universe is a work

of art. And it is impossible to understand the role played by experience in the Thomistic philosophy of science except by coming to see the precise way in which art enters into the structure of the cosmos.

Towards the end of the long analysis of the meaning of nature carried on in the second book of the Physics, St. Thomas arrives at his well-known definition: "Natura nihil est aliud quam ratio cuiusdam artis scilicet divinae, indita rebus, qua ipsae res moventur ad finem determinatum."(25) A nature is something essentially rational; it is a divine logos. And this applies even to the purely material principle out of which cosmic reality is constructed.(26) The whole purpose of the study of nature is to come to know these divine logoi in their ultimate specific concretion.

Now at first glance, all this may seem to add up to an argument against complete dependence upon experience rather than one for it. For to say that the cosmos is constructed out of divine logoi might seem to indicate that it is a perfectly logical and perfectly rational system, and that it therefore lends itself more to deduction than to induction. As a consequence Meyerson

might seem to be justified in writing: "La science d'Aristote était non pas une physique, mais une logique . . Mais il est clair que, pour le maître du péripatétisme, aussi bien que pour ses sectateurs de l'antiquité et du moyen age, les deux se confondent puisque la nature ne peut être que logique."(27) Moreover, the immaterial universe is also a work of divine art, and yet the science which deals with it is not completely dependent upon experience.

As a matter of fact, however, there is a vast difference between the art which has formed the immaterial universe and that which has formed the material universe. For in the cosmos there is a plasticity and a malleability that is utterly foreign to a universe that is free of matter. And it is in this plasticity and malleability that the complete dependence on experience has its root.

Immaterial forms are fashioned by divine art, but only with respect to their existence. This does not mean that their essence is in no way formed by God; it merely means that this formation consists only in bringing the form into existence. Because of their simplicity, immaterial forms have no plasticity intrinsic to their very essence, and consequently within this realm of essence the art that

produces them cannot compose. Material forms, on the other hand, are fashioned by divine art, not only with respect to their existence, but also with respect to their essence. The very fact that they are not pure forms, that in their very essence there is a principle of indetermination that is susceptible of an infinite variety of determinations, gives them an intrinsic malleability that leaves free scope for composition. This principle of indetermination, this source of plasticity, is obviously prime matter, which is in potency to all forms. And all this brings us back to something we saw in Chapter II in connection with the similarity between the study of nature and practical knowledge: as we descend the hierarchy of beings the operabilitas of things increases.

But perhaps we can give clearer outline to this point by having recourse to a rather crude illustration, drawn from the realm of mathematics. Between any two given numbers in the series of integral numbers there is only a finite multiplicity of numbers. And the numbers in this multiplicity are already predetermined. In order to actualize them a simple process of designation is sufficient. But between any two points in a continuum there is an infinity of points, and these points are not

predetermined. In order to actualize a certain magnitude a simple process of election is not sufficient. There is required a previous process of determination by which the magnitude in question is carved out, so to speak, of the potentiality of the continuum.

In somewhat the same way, we may say that between any two given angelic species in the hierarchy of the separated substances only a finite number of species is possible. This is not a limitation of God's power to imitate His essence in immaterial forms since just as there is no superior limit to the series of integral numbers so there is no superior limit to the hierarchy of separated substances which God can create. But between any two given material species, no matter how close they may be to each other, an infinite number of other species is possible. Immaterial forms, like integral numbers, are predetermined; their actualization consists in a simple process of election by which existence is given to them. But material forms are not predetermined; if they were, prime matter would not be pure potentiality -- there would be a latitatio formarum. That is why previous to the process of election by which existence is given to them there must be a process of composition by which their very essence is formed. In other

words, the production of immaterial forms merely consists in giving existence to essences already predetermined in the divine exemplary ideas; there is no composition in these exemplary ideas themselves. But in the case of material beings there is composition in the very exemplary ideas according to which they are produced.

In the mathematical world nothing is formed in the true sense of the word; nothing depends upon art in the sense of depending upon free determination, for in mathematics all things are analytical. And if mathematics is called an art, it is only on the sense of its being a speculative art, like logic. In the metaphysical world there is formation by art in the sense of dependence upon free determination, but only with respect to existence. But in the physical world there is formation both in the realm of existence and of essence. The material universe is essentially plastic.

That is why there is no way of arriving at a more profound view of the cosmos than by seeing it as a work of art. In spite of his tendency to look upon the universe as essentially mathematical, Sir James Jeans touched upon this truth when he wrote: "To my mind, the

laws which nature obeys are less suggestive of those which a machine obeys in its motion than those which a musician obeys in writing a fugue, or a poet in composing a sonnet."(28)

But in order to understand just how completely and essentially the cosmos is a work of art it is necessary to recall that because of its transcendental freedom, divine art is not tied down to the vias determinatas that are characteristic of human art. In this respect divine art is similar to prudence which proceeds per vias determinandas. Divine art can dominate contingency in a way that completely transcends human art; it can order it with infinite finesse. In fact, divine art shines nowhere with greater brilliance than in the realm of indeterminism and chance. And in the Thomistic view of things, the physical universe is essentially immersed in contingency, simply because it is essentially material. That is why the divine logos that is found everywhere in the cosmos is not the perfectly analytical rationality that is found in the mathematical world, nor the type of rationality that is found in the metaphysical world. It is essentially an artistic logos -- ratio artis divinae -- which orders contingency without destroying it. And a greater calumny could hardly be levelled against the Thomistic view of the cosmos than to

say that in it physics and logic coincide since the universe is a perfectly logical system. One has only to read the remarkable passages written by Aristotle, St. Thomas and Cajetan on the part that contingency and chance play in the universe to appreciate the falsity of this charge. The Peripatetic and the Spinozistic universes are completely antipodean.(29)

All this helps us to understand the part that experience plays in natural science. For as we saw in Chapter II, in the study of nature we stand before the universe as before a work of art. There is no way of telling a priori what an artist is going to do. One has to wait to see what he actually accomplishes. Nor is it possible to deduce from the first general outlines the particular details that will eventually enrich the composition. The only way in which a priori knowledge may be had of a work of art is for the artist to reveal what he intends to do. Something of this nature has actually occurred in the case of the angels, into whose intellects God infused the intelligible species of all the things which were to come from His creative art. But for us whose knowledge is posterior to things, the only way in which we can get to know nature is by ex-

perience. It is true that given the subject of a certain work of art some vague generalities may immediately be known about it. Given, for example, the fact that an architect is going to build a house, there are some general things common to all structures which serve as shelters that we can immediately know about it. These do not depend upon the free disposition of the artist. But as soon as we wish to come down to particularities we become dependent upon the free will of the artist. For there is an infinity of ways of making houses. In somewhat the same way, given the idea of a material universe, there are some things that we can immediately know about it. We can know for example that man must exist in it, since man is the raison d'être of the whole universe. But there is an infinity of ways in which the material universe in its evolution may prepare for the final production of man. From the beginning the cosmos has been in a continual process of formation and artistic composition. That is why there is a great deal of truth in Plato's idea of the demiurge which constantly works the world. And the only way to discover the actual line of species that has led up to man is by natural history, as St. Augustine has pointed out.(30) This brings us back to the profound significance of the "erit" in the passage

of Aristotle quoted in connection with the question of the relation between physics and practical knowledge. Natural things are not knowable except in the order of existence. The only way to get to know them is by knowing them as existing, that is to say by experience. As we remarked in Chapter II, the study of nature, because of its likeness to practical knowledge, must be built up out of bits garnered from experience. This constitutes a great difference between the science of nature and the other sciences.

There is, then, great wisdom in Aristotle's remark that it is noble to soil one's hands in experiments because by so doing one gets to know the art of Him who made all things. There is all the difference in the world between a "naturalist" and a peripatetic. The former merely delves deeper and deeper into the obscurity of matter. His knowledge is something like the cognitio nocturna of the fallen angels, because it is not referred to God. But whereas the end of his study is night, the end of the study of the peripatetic is light -- the light of divine intelligence, for the deeper he delves into matter the closer he is coming to divine art, since he is getting into more intimate contact with things in their plasticity. The farther advanced science gets towards concretion, the more it gets into the

realm where divine art composes more than anywhere else.

That is why every true Thomist has a profound respect for experience. For it takes the place of the infusion of the angelic species; it gives a share in the scientia visionis of God. And the farther advanced the student of nature gets in experience, the more his knowledge becomes like that of the angels which depends directly upon the divine species -- the more he participates in the scientia visionis of God. And in this connection it is interesting to note that if the term of this increase in experience could be realized, if the ultimate concretion could be reached, there would be a complete destruction of experience, for there would be perfect a priori knowledge. This is just one instance of a very significant truth which we shall examine in some detail in Chapter XI, namely that if the term of the tendency of experimental science could be reached there would be a contradiction. "L'esprit humain est absurde par ce qu'il cherche; il est grand par ce qu'il trouve."(31)

The conclusion that this discussion imposes upon us is that every part of the study of nature is dependent upon experience, but not in the same degree. The gener-

alities with which this study begins are not a priori hypotheses, as so many critics of Peripateticism are inclined to think. They are truths that are drawn from experience. But precisely because they are so general and superficial, and because they are the truths that are the most proportionate to our minds, they do not demand a great deal of experience; it is comparatively easy for the mind to disengage them from the world of sense. In order to arrive at the general nature of motion, for example, one simple experience with any kind of motion, such as the fall of a leaf, the movement of a finger, or a change of color in the sky is sufficient, for everything that can be known about the general nature of motion is contained perfectly and completely in any one of these examples. But in order to get at the nature of the special type of mobility that is proper to a particular natural species it is necessary to have recourse to long and complex experimental research. In other words, as we advance towards concretion, the dependence of the mind upon experience increases. And it is perhaps the relative simplicity of the experience that is required for the generalities which mark the beginning of the study of nature, and the comparative ease with which the mind disengages them that have led to the erroneous opinion that they are

nothing but abortive, hastily formed and ill-founded generalizations. (52)

But perhaps at this point one might be tempted to object: did not Aristotle frequently have recourse to hypotheses that were not fully founded in reality? Assuredly - and so has every other scientist worthy of the name who has really understood the nature of science, from Thales to Einstein. And this applies even to Newton, in spite of his well-known dictum: hypotheses non fingo. Newton merely failed to grasp the full significance of the method which he put to such good advantage. Hypotheses, as we shall bring out presently, are of the very essence of the study of nature. And to admit that Aristotle had recourse to them is simply to say that while on the one hand he had no part with the aprioriism of Descartes who spurned sense experience and wished to deduce more geometrico even such specific elements in nature as "the heavens, the stars, the earth, and on the earth: water, iron and minerals," (53) or the other hand he was far from falling into the naive empiricism of Francis Bacon. Although both Descartes and Bacon are counted among the principal founders of modern science, it is certain that modern science has sprung neither from the rejection of experience of the one, nor the

rejection of hypothesis of the other, but from a union of experience and hypothesis, such as is found in the doctrine of Aristotle.

But were not the hypotheses of Aristotle hastily formed? The answer is yes and no. For in a sense all good scientific hypotheses are hastily formed. Of their very nature they must anticipate reality; they must reach beyond the actual deliverances of experience. From this point of view a scientist who is too cautious is a poor scientist. It is true that as we look back now from the vantage point of many centuries of scientific progress some of the hypotheses of Aristotle look extremely precipitant. But, as we suggested in Chapter I, is it so certain that when as many centuries of progress have passed over the hypotheses of Einstein they will not appear just as precipitant as the Aristotelian hypotheses look to us today? The following well-known passage of Poincaré is extremely relevant here:

> Chaque siècle se moquait du précédent, l'accusation d'avoir généralisé trop vite et trop mal. Descartes avait pitié des Ioniens; Descartes à son tour nous fait sourire; sans aucun doute nos fils riront de nous quelque jour.
> Mais alors ne pouvons-nous aller tout de suite jusqu'au bout? N'est-ce pas le moyen d'échapper à ces railleries que nous prévoyons? Ne pouvons-nous nous contenter de l'expérience toute nue?

> Non, cela est impossible; ce serait méconnaître complètement le véritable caractère de la science. Le savant doit ordonner; on fait la science avec des faits comme une maison avec des pierres; mais une accumulation de faits n'est pas plus une science qu'un tas de pierres n'est une maison."(34)

In connection with this question of hypothesis one often encounters the charge that the Peripatetics were notoriously guilty of abitrarily and artificially forcing facts to fit into preconceived theoretical frames. We do not believe that this charge is justified. For, in the first place, it is something that was explicitly and strenuously combatted by Aristotle. In the second book of the De Coelo, for example, he writes:

> In fact their (the Pythagoreans') explanation of the observations is not consistent with the observations. And the reason is that their ultimate principles are wrongly assumed: they had certain predetermined views, and were resolved to bring everything into line with them.. But they, owing to their love for their principles, fall into the attitude of men who undertake the defence of a position in argument. In the confidence that the principles are true they are ready to accept any consequence of their application. As though some principles did not require to be judged from their results, and particularly from their final issue. And that issue, which in the case of productive knowledge is the product, in the knowledge of nature is the unimpeachable evidence of the senses as to each fact. (35)

Moreover, a number of cases could be cited in

which the great respect they had for sense experience led them to formulate points of doctrine that could only with some difficulty be harmonized with their fundamental principles. An example which immediately suggests itself is that of the doctrine of incorruptible matter. Because sense experience revealed no other changes in the heavenly bodies except local motion, they were led to the doctrine that these bodies were intrinsically incorruptible, and that consequently the prime matter which entered into their composition was different from that found in terrestrial bodies. We do not say that it is impossible to reconcile this with the pure indetermination of prime matter. In fact even today, after science has shown that the celestial bodies are susceptible of the same intrinsic changes as terrestrial bodies, and made up of the same stuff, we do not think it possible to prove apodictically that incorruptible matter cannot exist somewhere in the cosmos. Yet this reconciliation demands considerable ingenuity, and if the peripatetics had had less respect for sense experience it would have been a good deal easier to arrive a priori at the conclusion that the celestial bodies were capable of intrinsic mutations.

Another example of this kind is found in the

doctrine of spontaneous generation. This doctrine was formulated because sense experience revealed the generation of living beings out of putrefying matter, and at the time there were no adequate means for detecting the fact that eggs had previously been laid in the decaying mass. Here again we have a doctrine which was adopted in order to save sense experience even though it could only with considerable difficulty be reconciled with the basic principle of the essential difference between living and non living matter.

One of the most common objections brought to bear against peripatetics is that they failed to recognize the hypothetical character of their hypotheses, that they consistently mistook them for certain principles. In order to assess the justice of this charge we must consider a few texts. Speaking of the theory of the incorruptibility of the matter of celestial bodies, Aristotle remarks:

> The more evidence of the senses is enough to convince us of this, at least with human certainty. For in the whole range of time past, as 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.(36)

Commenting on this text, St. Thomas has the following to say:

> Secundum signum ponit ibi; Accidit autem hoc et per signum etc.: quod quidem accipitur ab experientia longi temporis. Et dicit quod id quod probatum est per rationem et per communem opinionem, accidit, idest consequitur sufficienter; non quidem simpliciter, sed sicut potest dici per comparationem ad humanam fidem, idest quantum homines possunt testificare de his quae parve tempore et a remotis viderunt . . . Hoc tamen hoc est necessarium, sed probabile. Quanto enim aliquid est diuturnius, tanto maius tempus requiritur ad hoc quod eius mutatio deprehendatur; sicut transmutatio hominis non deprehenditur in duobus vel tribus annis, in quibus deprehenditur transmutatio canis, vel alicuius alterius animalis brevioris vitae habentis. Posset igitur aliquis dicere quod, etsi coelum sit naturaliter corruptibile, est tamen tam diuturnum quod totum tempus cuius memoria potest haberi non sufficiat ad deprehendendam eius transmutationem. (37)

In the second book of the same work, Aristotle writes:

> Duabus autem dubitationibus earum, de quibus merito utique quilibet dubitabit, tentandum dicere quod videtur; dignum esse reputantes promptitudinem magis imputari verecundiae quam audaciae, si quis, propter philosophiam stare, et parvas sufficientias diligit, de quibus maximas habemus dubitationes.(38)

St. Thomas' commentary on this passage is extremely enlightening:

> Dicit ergo primo quod, cum circa stellas sint duae dubitationes de quibus rationabiliter quilibet potest dubitare, tentare debemus dicere circa istas dubitationes id quod nobis videtur; ita scilicet quod non reputemus dignum esse quod promptitudo hominis considerantis huiusmodi quaestiones magis debeat imputari verecundiae, idest honestati vel modestiae, quam audaciae, idest praesumptioni; si tamen ille qui huiusmodi dubitationes considerat, diligat etiam parvas sufficientias, i.e. parum sufficientes rationes, ad inveniendum de illis

> rebus, de quibus habemus maximas dubitationes; et hoc propter desiderium quod quis habet ad philosophiam, ut scilicet eius principia stent, idest firma permaneant...
> Illarum (Eudoxi, Aristotelis, et Ptolemaei) tamen suppositiones quas adinvenerunt, non est necessarium esse veras: licet enim, talibus suppositionibus factis, apparentia salvarentur, non tamen oportet dicere has suppositiones esse veras; quia forte secundum aliquem alium modum, nondum ab hominibus comprehensum, apparentia circa stellas salvantur. Aristoteles, tamen, utitur huiusmodi suppositionibus quantum ad qualitatem motuum, tamquam veris.(39)

Another very significant text is found in the Summa:

> Dicendum quod ad aliquam rem dupliciter inducitur ratio. Uno modo ad probandum sufficienter aliquam radicem; sicut in scientia naturali inducitur ratio sufficiens ad probandum quod motus coeli semper sit uniformis velocitatis. Alio modo inducitur ratio, quae non sufficienter probet radicem, sed quae radici iam positae ostendat congruere consequentes effectus; sicut in astrologia ponitur ratio excentricorum et epicyclorum ex hoc quod, hac positione facta, possunt salvari apparentia sensibilia circa motus coelestes: non tamen ratio haec est sufficienter probans, quia etiam forte alia positione facta salvari possent.(40)

We believe that these texts, which were completely ignored by historians until several of them were brought to light by Pierre Duhem,(41) establish beyond a doubt the fact that Aristotle and Saint Thomas were acquainted with the hypothetical method employed by modern science.

It would be interesting to examine each of them

in detail. But for our purpose a summary conclusion will suffice. We believe that they make it abundantly clear that the peripatetics had accurate knowledge of the hypothetical method that has become the very soul of modern science. The fact that in individual cases they may have erroneously believed that they had apodictic arguments in favour of certain propositions when such arguments did not exist, does not in any way invalidate this claim. As is evident from these texts, the position of Aristotle in this matter is less unambiguous than that of St. Thomas. But there is ample reason for believing that even the former had great diffidence about the truth of the theories he proposed, that he attributed to them the certitude that is necessary for working hypotheses, that he posited them as if they were true in order to save the phenomena. But whatever may be thought about the position of Aristotle, there can be no doubt about that of Aquinas. In the passages just cited from him there is an accurate description of the hypothetical method used in modern science. Accuracy and [illegible] certitude.

It is not without interest to note that the theories to which St. Thomas attributed only probability were precisely those upon which rested the whole doctrine of the structure of the heavenly spheres, which has seemed

so utterly naive to modern critics. What these modern critics fail to realize is that this doctrine saved the phenomena that were known at that time just as successfully as the theories of classical physics saved the phenomena that were known during the seventeenth and eighteenth centuries -- just as successfully as the theories of Einstein save the phenomena that are known today. It is extremely significant that nowhere do we find in the writing of those who are credited with being the founding fathers of modern science, such as Copernicus, Kepler and Galileo, anything that comes so close to a description of the true method of science as that found in the writings of Aquinas. It is true that Copernicus in his Commentariolus de Hypothesibus Motuum Caelestium seems to posit his fundamental principles as mere postulates: "si nobis aliquae petitiones . . . concedentur." But later in his De Revolutionibus Caelestibus Libri Sex his attitude is far less reserved. In his introduction to this latter book, Osiander brought out with great eloquence the true scientific method: "Neque enim necesse est eas hypotheses esse veras, imo, ne verisimiles quidem; sed sufficit hoc unum, si calculum observationibus congruentem exhibeant." But Kepler would have no part with such a doctrine: "Je n'hésite pas

à déclarer que tout ce que Copernic a supposé a posteriori et prouvé par l'observation, tout cela pourrait, sans nulle entrave, être démontré a priori, au moyen d'axiomes géométriques, au point de ravir le témoignage d'Aristote, s'il vivait." (42) Galileo distinguished between the point of view of astronomy in which the hypotheses have no other sanction except conformity with experience, and that of philosophy of nature which bears upon the objective nature of things. But if we are to believe Duhem (43) this was a purely theoretical distinction formulated to avoid the censures of ecclesiastical authority, and Galileo accorded full certitude to all of his theories. In any case there can be no doubt that throughout the reign of classical physics full certitude was universally attributed to doctrines which were in reality only hypothetical. And if today the hypothetical character of sciences has become generally recognized, it is undoubtedly due in large measure to the rude awakening occasioned by the downfall of Newtonian physics. St. Thomas did not need such an awakening. In spite of the fact that the physical theories he held saved the phenomena known at the time as successfully as modern theories save the phenomena known now, he was sagacious enough to recognize their hypothetical character.

But even more important than the consideration of the texts cited above is the consideration of the certitude that the propositions of experimental science enjoy de jure in the Peripatetic philosophy of science. And this requires an analysis of the relation between certitude and experience in the study of nature. Before embarking upon this analysis, however, at least passing attention must be paid to one last objection that is frequently proposed against the position we have been maintaining with regard to the importance of the role of experience in the Thomistic philosophy of science. It is this: if according to Thomism experience plays such an indispensable role in the study of nature, and particularly in that part of it which is to some degree advanced in the direction of concretion, why is it that St. Thomas and the medieval schoolmen were so notoriously remiss in the actual practice of experimentation. We do not hesitate to grant the premises upon which this objection is based. Aristotle was, as we have already pointed out, a great experimenter. But St. Thomas and the medievalists, with a few notable exceptions, such as St. Albert the Great, were not. There was, however, a reason for this. The medievalists were primarily theologians. This does not mean that there were not at the same time great philosophers, nor that theology

dictated to their philosophy in the manner usually described by historians. It merely means that their interest in philosophy was concentrated chiefly upon the problems that had a bearing upon theology and upon the problems that had the greatest significance for human life. They were moreover primarily interested in science in the full and perfect sense of the word, that is to say, science in which there is certitude, and as we shall see in a few moments, experimental science does not give true certitude.

Whatever may have been the actual practice of St. Thomas and his followers, the only important point is that in principle according to the Thomistic philosophy of science, the student of nature must, if he is to realize his purpose, be carried constantly forward toward fuller concretion, and this advance demands an ever increasing dependence upon experience. Here we run across a remarkably striking paradox. Auguste Comte, the father of Positivism, denied the necessity and validity of extended experimentation. He rejected, for example, what he called the abuse of extended microscopic research. (44) Nowhere do we find anything of this sort in the doctrine of Aristotle or St. Thomas, which, if we are to believe critics, was so thoroughly anti-positivistic. On the contrary, the very principles of this

doctrine demand unceasing experimentation and recourse to the most refined instruments of research available. It may readily be admitted that neither Aristotle nor St.Thomas ever anticipated the perfectibility of our means of observation and experimentation that modern progress has revealed, and that as a consequence some of the positions assumed by them were far more provisory than they suspected. But the fact remains that their conception of natural science demands a conformity with observation which must constantly increase both in breadth and in depth.

B. Experience and Certitude.

Let us begin our analysis of this problem by considering the following text of Aristotle:

> The science which is knowledge at once of the fact and of the reasoned fact, not of the fact by itself without the reasoned fact, is the more exact and the prior science. A science such as arithmetic, which is not a science of properties qua inhering in a substratum, is more exact than and prior to a science like harmonics, which is a science of properties inhering in a substratum; and similarly a science like arithmetic, which is constituted of fewer basic elements, is more exact than and prior to geometry, which requires additional elements. What I mean by 'additional elements' is this: a unit is substance without position, while a point is substance with position; the latter contains an additional element. (45)

In this passage Aristotle brings out the three basic principles which determine the relative certitude found in the sciences. Although in writing this passage he did not have explicitly in mind the point which is of interest to us here, we may apply these principles to our purpose, which is to show that in the measure in which the study of nature becomes increasingly dependent upon experience, its certitude decreases.

The first principle laid down by Aristotle is this: a science which not only gives us facts (the quia) but also the reasons for the facts (the propter quid) is more certain than a science which provides only the facts without the reason for them. Now as increasing experience carries us forward towards fuller concretion, the abundance of facts continually grows, but at the same time it becomes constantly more difficult to disengage the propter quid to explain these facts. And the reason for this is fairly evident: the more we advance, the more we approach things under the aspect in which they depend completely upon the practical knowledge of God, and scientia visionis, which involves something that is outside the realm of knowledge, namely the divine free will.(46) It is precisely because it eventually becomes impossible to discover a

proper propter quid in the parts of natural doctrine that are advanced towards concretion that it becomes necessary to reach up to mathematics to find a substitute propter quid through a process of subalternation. That is another way of saying that as we emerge from the part of the study of nature that is most conformable to our minds it becomes necessary to substitute the science that of all the sciences is most in harmony with the human intellect.(47)

The second principle of Aristotle consists in this that a science which deals with a subject is less certain than a science which does not. In his commentary on this passage, St. Thomas explains what Aristotle means by the term "subject": "Et accipitur hic subjectum pro materia sensibili;... incertitudo causatur propter transmutabilitatem materiae sensibilis; unde quanto magis acceditur ad eam, tanto scientia est minus certa."(48) Now just as a science which deals with sensible matter is less certain than one that does not, so that part of the study of nature which experience has carried deeply into concretion is less certain than that part which is not so completely immersed in concrete sensible matter.

In his third principle Aristotle states that a

science which has to do with fewer elements is more certain than one in which the elements are more numerous. This has a direct application to our problem. For increasing experience carries the study of nature forward from generality to greater specificity, in such a way that the proper distinctions of things gradually emerge. This is why the further the study advances the greater becomes the need for more particular and consequently more numerous principles. For the proper differences of the natural species cannot be deduced from each other, as we have already pointed out. Hence the necessity of as many principles as there are natural species to be known. It may be said that the number of principles in experimental science tends towards infinity. Each natural species is a primary datum and the source of a number of original propositions. And the multitude of possible natural species is infinite. It is true that the theories of evolution will attempt to reduce this great variety to a basic unity, but these theories presuppose experience with the original variety and must succeed in leading back to it.

From all this it follows that there is an inverse proportion between the dependence of natural science upon experience and the degree of certitude that is possible

in it. That is why the prudent student of nature will commit himself less categorically and with greater reserve and with more abundant qualifications the more he advances towards concretion. As Aristotle points out, "since the truth seems to be like the proverbial door, which no one can fail to hit, in this respect it must be easy, but the fact that we can have a whole truth and not the particular part we aim at shows the difficulty of it."(49) And it is for this reason that the universal propositions advanced in the more concrete parts of natural doctrine do not enjoy true certitude. Nor is it any cause for wonder that in a science which deals with mobile being, certitude so quickly fades into mere probability.(50) But it is necessary to try to analyse this question more accurately. In the general propositions which the mind first disengages from its experience with cosmic reality, perfect certitude is possible, for in such propositions an analytical relation exists between subject and predicate. For example, there is an analytical relation between substantial mobility and substantial mobility and substantial composition of matter and form. In propositions of this kind the mind not only grasps the quia, but also the propter quid. That is why the parts of natural doctrine which are made up substanti-

ally of propositions of this kind, i.e. the Physics and the De Anima constitute true scientific knowledge in the strict sense of the word. In this case there is direct correspondence between the clarity which these propositions have for us and their certitude, in contrast to what is found in theology whose principles though extremely obscure for us have greater certitude than principles which have greater clarity for us.

But as natural science advances towards concretion and dependence upon experience increases, analytical relations become less and less apparent. Propositions become more and more experimental. There ultimately comes a point (and it is very quickly reached) at which the propositions are purely experimental, that is to say, they merely formulate what experience presents to the senses. From that point forward no true scientific knowledge in the strict sense of the word is possible. The propositions give only the quia and not the propter quid. In other words they are not analytic, but purely synthetic; It is true, as we shall try to bring out presently, that the mind will not rest satisfied with this pure synthesis. It will try to triumph over it by the projection of its own subjective logos by the erection of a "propter quid", in such a way

that in a sense it will be able to arrive at synthetic a priori judgments. But in the last analysis the propositions remain synthetic and never become analytic. At this juncture we have arrived at the frontiers of philosophy and experimental science.

John of St. Thomas has brought out this point with considerable precision:

> Non est idem propositio per se nota quod intuitiva sive per experientiam sensuum nota, quia quod sensu cognoscitur, non cognoscitur ut propositio, sed ut simplex objectum apprehensum, neque ex sola explicatione terminorum innotescit, sed quia experientia externa attingitur. Et sic nivem esse album, licet in sensu sit per experientiam notum, in intellectu tamen non est propositio nota ex terminis per se connexis, sed potius in materia contingenti. (81)

Even though all experience that has ever been had with snow has presented it as white, this experience does not prove that it is contradictory for snow not to be white. It remains possible, of course, that there is some incompatibility between the essence of snow and any other color, and further experience will render this possibility increasingly probable. But of itself experience will never transform this probability into certitude. Nor does it do any good to have recourse to the principle that what happens ut in pluribus comes from nature. For though this principle

is unquestionably valid, it does not settle the problem about what nature is involved. In other words, the regularity of the whiteness of snow is obviously a sign that it is coming from nature. But is it coming from the nature of the snow? Perhaps it derives from some atmospheric condition or complexity of conditions proper to our planet. There are so many natures involved in even such a relatively simple process as the production of snow that it remains impossible to trace the regularity back to its source. It becomes apparent, then, that the proposition "snow is white" is not universal and necessary at the same time. In so far as it is proposed as necessary, it is not universal, but restricted to the snow that has been met this far in experience. In so far as it is proposed as universal it is not necessary. As a consequence, it cannot be a scientific proposition which must be both universal and necessary. Hence it is evident that the universalization that is effected in experimental science is purely functional. That is to say, when propositions are universalized without evidence, there must be a functional reason for doing so. In other words, when we act "as if" this does not mean essentially that in so doing we may be right, but rather that in so doing we may get somewhere.

It is clear, then, that the propositions of experimental science remain completely tied down to experience. It can never truly abstract from experience because experience is never complete. This means that they can never effectively rise above the realm of singularity. In this sense all experimental science is essentially nominalistic. That is why experimental science must ever remain in a state of becoming. And we mean by this something over and above the progress that is characteristic of all human science. We mean that the very genesis of the concepts employed in experimental science is never terminated. There must be a constant recourse on the part of the intellect to sense experience which is immersed in contingency and the flux of time. And this flux and contingency will ever remain refractory to complete abstraction. It will always be possible that further experience may change to a greater or less degree of concepts already formed, or at least the relations between them suggested by previous experience. That is why, as Professor DeMonimik has pointed out, history pertains to the very essence of experimental science, whereas the disciplines that are sciences in the strict sense of the word are only accidentally implicated in history. And in this connection it is interesting to

note that even if per impossibile the cosmos were the perfectly rational system that the historians have wished upon Peripateticism, it could never be known as such by the methods that are proper to experimental science. Its necessary structure would only be a dialectical limit which experimental science could constantly approach without reaching.

All this discussion about the part played by experience in the study of nature leads inevitably to the problem of induction over which logicians have labored so much, especially since the time of Hume. We believe that much of this labor has been futile because a few basic distinctions have been neglected. And perhaps the best way to embark upon this question is by citing the following significant dictum of John of St. Thomas:

> Omnis nostra speculatio dependet ab inductione sicut dependet a sensu et experientia; unde si propositiones universales alicuius scientiae non sunt ita abstractae et communes quod ex quocumque individuo manifestari possit ipsarum veritas, sed ex plurium numeratione et experientia pendeat, sicut scientiae naturales, non sunt ita certae sicut aliae scientiae abstractiores et communiores, ut metaphysica et mathematica, quorum principia in uno individuo habent totam certitudinem ut: quodlibet est vel non est.(53)

When John of St. Thomas says that all of our

speculation depends upon induction just as it depends upon the senses and experience, he is evidently taking the term in a rather broad sense, in a sense in which it is coterminous with any deliverance of sense experience to the intellect. But under this generic notion it is possible to distinguish three types of induction. In the first place, induction may be understood to mean the abstraction of universal concepts from singular objects. Taken in this sense, it is found in all of the sciences and in all intellectual activity.

Secondly, it may signify the arrival at analytic propositions from sense experience. And here it must be noted that the term "analytic propositions" is not taken in the superficial sense in which it is understood by Kant. It means all propositions in which the predicate is for any reason necessarily (and therefore universally) connected with the subject. Since all sciences in the strict sense of the word must begin with necessary principles, and since all of our knowledge is drawn from sense experience, this type of induction is found in all of the disciplines which are truly sciences, that is to say in mathematics, in metaphysics, and in philosophy of nature. The way in which this induction takes place is not in every respect the same for all the sciences. Mathematics presents an especially particular

case about which much has been written in recent years. It is not to our purpose to embark upon this question here, and it is sufficient to point out that even mathematical principles, in spite of their intuitive and a priori character are originally drawn from sense experience, even though they are not found there in the state of abstraction and perfection that is characteristic of the mathematical world. (84) In metaphysics principles applicable to the whole range of being can be drawn from sense experience for they are realized in sensible being not because it is sensible, but because it is being. In philosophy of nature analytic principles governing mobile being are disengaged from experience, and unlike metaphysical propositions, are enunciated in terms of sensible matter. And in all of these cases the passing from the singularity and contingency of experience to the universality and necessity of analytic principles is not logically invalid, simply because the basis of the universality and necessity is not the fact that the subject and predicate are united in experience, but the fact that the mind can see that the predicate pertains to the very nature of the subject. For example, the principle that the whole is greater than any of its parts is drawn from experience in which concrete

wholes are presented as greater than concrete parts, but the universality and necessity of the principle is founded on the analytical nexus which the mind discovers between the subject and the predicate.

Perhaps the passage quoted above from John of St. Thomas may give rise to doubt about the possibility of such analytic principles in philosophy of nature, for at first glance he may seem to restrict them to metaphysics and mathematics. A more careful reading of the text, however, suggests another interpretation. In comparison with all of the propositions found in natural science, the number of truly analytical propositions is almost infinitesimally small, and that is why synthetic propositions may be considered as characteristic of the study of nature. Moreover, even the few analytical propositions that are found in philosophy of nature, though fully certain in themselves, are less certain in comparison with metaphysical and mathematical principles because of the materiality involved in them.

The third type of induction is the one that is of special interest for us. It is the type that is characteristic of experimental science, and it takes the form of an illation in which the mind progresses from a

multiplicity of singular experiences to a judgment which is proposed as universal, but which can never be anything more than tentatively universal because the nexus of the judgment is based merely upon repeated experience and not upon the apprehension of a necessary connection between subject and predicate. Such propositions, as we have already pointed out, can never be anything more than probable. It is true that as the experiences are multiplied the probability may in some cases increase to the extent of reaching practical certitude, but it can never reach the infinite limit of theoretical certitude. It is our contention that experimental science is made up completely of this probable knowledge, and that as a consequence it is not science in the strict sense of the word. But lest misunderstanding arise, it must be noted immediately that this probability refers only to universal propositions and there is no intention of calling into question the certitude of facts established by experimental science. The whole point is that science is constituted essentially of universal propositions and not of singular facts.

The type of induction we have just described is known as ascending induction. There is also a corresponding descending process in which the mind passes from a

universal proposition to singulars. This descending induction is often confused with deduction. There is, however, a vast difference between the two, for like ascending induction, descending induction lacks a true middle term. (55) This descending induction is also used extensively in experimental science. For since the universal proposition arrived at by ascending induction is only tentative it must be continually submitted to further experience for verification, and it is by a process of descending induction that this submission takes place. It remains true, of course, that deduction plays an important role in physics, but that is principally because of the introduction of mathematics which is a true deductive science.

The most important point which emerges from this discussion is the clear cut distinction between the second and third types of induction. Most of the difficulty that has arisen about the nature of induction has resulted from a confusion of these two. Until fairly recently it was customary to identify the third type with the second in the sense that the induction of experimental science was believed to give absolute certitude. Until the downfall of classical physics, nothing seemed more certain than Newtonian science. But since this downfall occurred it has

become customary to identify the second with the third and to extend the lack of certainty that is characteristic of experimental science to all science,[56] and indeed to all human knowledge.

This distinction is important because upon it is based the distinction between philosophy and experimental science, as has already been suggested. The principles of the philosophy of nature are drawn from experience by induction, but because they are analytic, it is possible to infer from them conclusions that are certain. If the inference is good, the conclusions are necessarily true. These conclusions must indeed terminate in the senses in the way already explained in Chapter II. But this does not mean that they have to be submitted to sense experience for further verification -- since they are already necessarily true. In experimental science, on the other hand, the principles drawn from experience are only probable. Certain conclusions may be inferred from them, but even if the inference is good the conclusions are not necessarily true. That is why they must be submitted to observation and controlled by further experience. Experimental science is, consequently, doubly experimental -- both in its origin and in its terminus. Its principles are drawn from experience

and this "drawing" does not consist in a strict disengagement; the principles remain tied down to the actual experience already achieved. The conclusions of experimental science must be put back into experience again. Philosophy of nature on the other hand is experimental only in its origin and even here it transcends experience in the sense that the nexus of its propositions is not based upon experience. That is why, in opposition to the term "experimental" it may be called "rational".

And now, having arrived at this important distinction between philosophy and experimental science, we must pause to examine its nature in some detail.

4. Philosophy and Experimental Science.

It has become customary for modern writers to point out that in the writings of Aristotle no distinction between philosophy and experimental science is encountered. The inference that one is invited to draw from this observation is either that Aristotle was unacquainted with experimental science[57] or that he erred in failing to recognize that these two types of natural doctrine are formally

and specifically distinct sciences in the strict sense of the word.[58] Perhaps enough has already been said to show that the basic structure of modern experimental science is clearly and accurately outlined in the writings of Aristotle, and in Chapter II we pointed out why Aristotle failed to recognize the formal and specific distinction upon which so much stress has been laid by some modern Thomists: such a distinction neither exists nor can exist.

Does this mean that Aristotle recognized no distinction between the two parts of natural doctrine that have become known as philosophy of nature and experimental sciences? In the first book of De Partibus Animalium we run across the following passage: "It may, however, be asked, of what mode of necessity are we speaking when we say this. For it can be neither of those two modes which are set forth in the philosophical treatises."[59] These few lines make it clear that Aristotle recognized a distinction between the parts of natural doctrine that are advanced in the direction of concretion and those which deal with generalities. To the latter he applied the term "philosophical" and the evident implication is that the former are in some sense not philosophical. Yet later on in the same work he tells us that it pertains to the philosopher to handle the subject of

this treatise.[60] This seems at first glance to constitute a paradox. Yet we feel that a closer examination will reveal that these two texts implicitly suggest the correct solution of the problem of philosophy and science. They suggest both the precise way in which the two parts of natural doctrine are distinct and the way in which they must be kept united.

In the first place, let us recall that the term "philosophy" had for the ancients a much broader meaning than the one it now enjoys. It was, in fact, coterminous with all human science taken in the strict sense of the word (with the exception of theology for the medievalists). Consequently, when Aristotle says that the more abstract parts of natural doctrine are philosophical whereas the more concrete parts are not, he is simply saying that the former are strictly scientific and the latter are not. And this is precisely the conclusion to which our analyses have already led us. In Chapter II we demonstrated the impossibility of more than one true science in the first degree of abstraction. And earlier in this Chapter we saw that because of the type of induction employed by experimental science, it can never effectively rise above singularity to the point of achieving true universal and necessary propositions. We saw that whereas in philosophy of nature the

nexus of the propositions is strictly formal and analytic, in experimental science the nexus is material and synthetic. There are, of course, two types of material and synthetic nexus. There is, first of all, the completely material and synthetic nexus found in such propositions as: "this table is white." In this case we know that the nexus is merely material and synthetic because we have seen tables which are not white. But in the case of the propositions of experimental science we are not sure that the nexus is merely material and synthetic. In fact we tentatively arrive at something more than that. That is to say, there is a movement away from pure materiality and pure synthesis towards formality and analysis. Nevertheless this remains a purely dialectical limit that can never be reached. In other words, whereas in philosophy of nature we get at both the quia and the propter quid, in experimental science we get at only the quia. But we do not rest content with the mere quia. There is a constant striving towards the discovery of a propter quid. This is carried out by means of hypothesis. But the validity of every hypothesis depends upon an experimental confirmation, and this experimental confirmation gives us only an experimental proposition, and thus we have set out upon an infinite series of interplays between experience and hypothesis. All this

amounts to saying that all the concepts of experimental science ever remain incomplete and indefinitely open and perfectible. Because descending induction can never reach experience in such a way as to close the concept and make of it a true universal, experimental science though constantly striving towards formal abstraction never actually arrives at it nor at its certitude. The perfect certitude that experimental science seems to possess is, in the last analysis, nothing but an illusion deriving from the certitude that it is possible to have of a singular object or a group of singular objects.

Since, then, experimental science does not arrive at true formal abstraction, it cannot be a science in the strict sense of the word. And if it was experimental science that Locke had in mind when he said that natural philosophy is not capable of being made a science, he was quite correct.(61) As has already been stated, experimental science belongs to a type of knowledge which must be termed "dialectical." We shall devote the whole of Chapter V to an analysis of the meaning of this term, and for the moment it is sufficient to have pointed out in a general way the nature of experimental science in order to make evident the precise way in which it is

distinguished from philosophy of nature. It should be apparent from what has been said that the frontiers between philosophy and science are something definite and clear cut and not the nebulous thing that so much of the discussion of the question has made them. Just as soon the study of nature has arrived at the point at which the nexus of its propositions depend only upon experience, the frontiers between philosophy and experimental science have been reached. And it must be said in passing that if the reason why the term "experimental" is applied to science is not that the propositions are purely experimental, we know of no definite and absolute meaning that can be attributed to it.

At this juncture it is necessary to consider in some detail the distinction between philosophy and experimental science traditionally proposed by scholastic manuals: experimental science studies reality in terms of its proximate causes, whereas philosophy studies it in terms of its ultimate causes. We believe that in this distinction there is a extremely pernicious ambiguity that has confused the whole question of the relation between philosophy and science. For the expression "ultimate Cause" may be taken to mean two different things. It may,

first of all, mean the principles which enjoy true universality of causality, and not merely universality of predication. These causes can be arrived at as such and in an absolute fashion only by means of what are known as the proximate causes. Thus it is possible to demonstrate in the De Anima that man is the last end of all the natural species. But the knowledge that this gives us, though certain, is extremely obscure and confused. The theories of evolution are an attempt to dissipate this confusion and to arrive at this end in the order of generation. And it is only by means of these theories that we can get at this ultimate cause which is man in a determined and absolute fashion.

But the expression "ultimate causes" may also be taken to mean the principles which have only universality of predication, that is to say, those encountered in the first part of natural doctrine. These causes may be called ultimate only in the sense that they are the farthest removed from what constitutes the essential and primary object of the study of nature -- the knowledge of things in their proper causes. They are not ultimate in the sense of being the terminus towards which the whole study of nature is orientated. In fact, they are at the opposite extreme.

That is to say, far from being the ultimate causes, they are the very first causes which the mind lays hold of in its initial contact with nature. Nor are they ultimate in the sense of being the most profound causes in the true sense of the word. For the most profound knowledge that one can have of nature is to know natural things in their proper causes, and the causes of which we are speaking are the most common that it is possible to discover. That is why from this point of view they provide us with the most superficial knowledge that it is possible to have of the cosmos. And it can be considered the most profound knowledge only by confusing the study of nature with the type of knowledge that is had in mathematics where the most known for us is also the most known in se. (62)

The following passage from the second book of the Physics brings out what Saint Thomas understood by profound cause:

> ... in naturalibus oportet semper supremam causam uniuscuiusque requirere, sicut contingit in artificialibus. Ut si quaeremus quare homo aedificat, respondetur, quia est aedificator; et similiter si quaeramus quare est aedificator, respondetur, quia habet artem aedificativum; et hic statur, quia haec est prima causa in hoc ordine. Et ideo oportet in rebus naturalibus procedere usque ad causam surpremam. Et hoc ideo est, quia effectus nescitur nisi sciatur causa; unde si alicuius effectus causa sit etiam alterius causae effectus, sciri non poterit nisi causa eius sciatur;et sic quousque perveniatur ad primam causam.(63)

It is fairly clear from these lines that the most important cause -- the cause which constitutes the proper goal of science, the cause which gives us the most profound view of the nature of things, is not the remote cause, but the proper cause -- the cause which accounts for the ultimate concretion of the effect.

We believe that the majority of modern Scholastics have confused the two meanings of "ultimate cause" just defined. And this confusion has led to a good deal of unfortunate misunderstanding about the true character of the study of nature. From it has come that false air of profundity that so many Scholastics have assumed in dealing with things which in reality constitute the most indetermined and confused knowledge that it is possible to have of nature. From it, too, has come a view which when analyzed can hardly be distinguished from Hegelian idealism. We have in mind the notion that by means of the most general considerations possible one succeeds in grasping the very substance of things. Scholastic manuals give the impression that in the De Anima, for example, one grasps the very essence of the soul, and that the study of bees and birds and horses has to do only with accidental modalities of the substance of the brute animal. If this were true, the general would

be identified with substance, as in the doctrine of Hegel, and the species would be only a kind of phenomenal mode, or ulterior elaboration of the substance, which is not of interest to the philosopher whose task is to get at the profound essence of things. In other words, what is the most clear and the most knowable for us would be the essential substance of things, that is the most clear and knowable in se. Early in this Chapter we have seen that this is diametrically opposed to Aristotelian and Thomistic doctrine.

From this same confusion has arisen a false view of the order in which nature should be studied. Instead of following the traditional Aristotelian and Thomistic order which begins with generalities and moves on towards fuller concretion, in such a way that experimental science is a prolongation of philosophy of nature, most modern scholastics have made the philosophy of nature an extension of experimental science in such a way that the former in one fashion or another depends upon the latter. This dependence is often proposed as being absolute. Thus Fulton Sheen, for example, writes: "Under no consideration must it be thought the philosophy of nature does away with any experimental science. As a matter of fact, it would cease to exist without them." (64) Such a position has led modern scholastics to

undertake such futile tasks as the demonstration of the doctrine of hylemorphism by means of physics and chemistry.

This view of the relation between science and philosophy is the one usually accepted among non-scholastic philosophers. Professor A.E. Taylor states the position in the following terms:

> The work of the Philosophy of Nature and Mind only begins where that of the experimental sciences leaves off. Its data are not particular facts, as directly amassed by experiment and observation, but the hypotheses used by experimental science for the co-ordination and description of these facts. (65)

It is obvious that if this were the true relation between philosophy and science the former would be even more dialectical than the latter. (66)

In some quarters the anteriority of philosophy of nature to experimental science is recognized in one fashion or another, but then philosophy often becomes nothing but a highly theoretical vanguard of science born of hasty generalization which science gradually supplants by its constant progress. "The increasing independence of natural scientific branches from philosophy from Aristotle's time to the present," writes Pascual Jordan, "has simultaneously also emptied philosophy of its original

content and problems."(67)

Some modern Thomists, while not making the dependence of experimental science upon philosophy complete and absolute, consider it nevertheless to be so essential that the constant progress of experimental science makes every treatise of the philosophy of nature extremely short lived. Thus Maritain says: "Je pense qu'un traité de philosophie de la nature, au maximum peut vivre une vie d'homme, cinquante ans, soixante-dix ans, si atuem in potentatibus, etcgenta anni -- et encore à condition d'être périodiquement remis à jour, à supposer qu'il ait des éditions successives; parce que ce traité de philosophie de la nature doit nécessairement avoir un contact intime avec les sciences des phénomènes, et ces sciences se renouvellent beaucoup plus rapidement que la philosophie."(68) We cannot subscribe to such an opinion. We believe that a treatise of philosophy of nature, if it is good when first written, can live far beyond the life of a man. We believe that it can live forever without any substantial change. In everything that is essential, the treatises of Aristotle and St. Thomas upon those parts of natural doctrine which are now known as philosophy of nature -- the eight books of the Physics and the three books of the De Anima -- are

just as alive today as when they were first written. All too many modern Thomists think that they have gone far in defending the perennial vitality of Thomism when they claim that although the writings of Aristotle And Aquinas on physical subjects are now obsolete, their metaphysics and moral philosophy remain eternally alive. It is safe to say that most of the Thomists who make such statements have never taken the trouble to give the Physics and the De Anima a close and intelligent reading, for such a reading would reveal that it is only in comparatively few and in extremely minor details that these treatises need revision. And the reason is simple: these treatises are essentially anterior to, and therefore independent of, experimental science. As we have already explained, in order to arrive at the general notion of the nature of motion Aristotle needed only the simple experience of the fall of a snow flake. The generic nature of motion was totally contained in this one instance and could be disengaged from it. If his analysis of this generic nature was correct, and we believe it was, then his definition of motion will ever remain unaffected by the innumerable highly complicated experiments subsequently made to determine the nature of motion in a more specific way.