PHILOSOPHY OF NATURE
LET THOMAS AQUINAS TEACH IT

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2012

PREFACE

Philosophy of nature is in a way the most important course in Philosophy. Metaphysics and philosophy of the nature of man are more important because what they treat, but these sciences are grounded in Philosophy of Nature. To understand the nature of man, one must first understand the basic principles of nature. And if philosophy/science of nature fails to discover any immaterial being, there can be no Metaphysics.

This work presents summaries and texts from Thomas' Commentary on Aristotle's *Physics*, along with his *De principiis naturae*. Find the full texts of these and others at http://www.josephkenny.joyeurs.com.

Thomas often states that for natural science, unlike mathematics, wide experience is necessary. This text presupposes familiarity with general science, especially familiarity with developments in astronomy, concerning the origin of the universe, and discoveries of its contents and activity. I have many videos that can go along with this text.

Philosophy of nature is indistinguishable from philosophy of science. The student should be familiar with the most prominent theories in circulation today, and be able to critique them. A starter in this direction is Anthony Rizzi' *The science before science: a guide to thinking in the 21st century* (Baton Rouge: Institute for Advanced Physics Press, 2004).

The order of this text is based on the general methodology Thomas provides in his Commentary on the *Posterior Analytics*, namely, that every science has a subject, principles and properties. The following chapters go from an introduction (1) to the subject of natural science (2), its intrinsic principles (2-4), its properties (4-9), and finally its extrinsic principles (11-13).

Plan of the course

1. Introduction: What is Philosophy of Nature in the scheme of philosophy and science
2. The subject of natural science and its intrinsic principles
3. Thomas' essay, *The principles of nature*
4. Chance and causality —since natural causes are the principles of demonstration
5. The meaning of motion and its various species —since motion is the basic property of natural things
6. Concepts subsidiary to motion, such as the infinite,
7. place, space, void,
8. time.
9. The three species of motion, with answers to objections to the possibility of motion
10. The divisibility of motion and rest —towards determining the efficient cause
11. The efficient cause of motion, and its requisites. Can it be eternal?
12. The existence of God: Three ways Thomas rejects, and his first 2 ways
13. The existence of God: The last 3 ways, and those in Thomas' *Commentary on John*

CHAPTER 1
DEFINITION OF PHILOSOPHY OF NATURE

What is science? (Book 1, Lesson 1)

Refer to the *Posterior Analytics* for a definition of science: It is knowledge of a universal fact through proper causes. Science (in Arabic *al-`ilm*, in Greek επιστημη) is a technical term for knowledge of a determined subject, an attribute which is the property of that subject (having the same extension) and the cause of that attribute, which is to be found in the nature (the form or matter) of the subject and also in external final and efficient causes. Such knowledge is demonstrative, because it is knowledge of the fact and the proper reason for the fact. Demonstration, in Aristotelian tradition, is not a means of discovery, but an analysis of knowledge already gained from experience and research.

The division of speculative sciences

Sciences are distinguished in two ways:

- By their relation to **matter**: since every science is in the intellect, and things are made intelligible to the intellect by their abstraction from matter, therefore according to their different relationship to matter there will be different sciences.
- By their **definition** of the subject: Since the middle term of demonstration in a science is a definition of the subject, according to different definitions there will be different sciences.

Consequently, according to the different relations to **matter**, expressed in different **definitions**, there will be different sciences:

1. There are certain things whose being depends upon matter, and which cannot be defined without matter, i.e. physical things.
2. There are certain other things which, although they cannot exist except in matter, nevertheless sensible matter does not enter into their definition, i.e. mathematical things.

The two differ as do "circle" and "plate". For a plate is in sensible matter, and sensible matter necessarily enters into its definition–for a "plate" is "circular"–and such are all **natural** things, as for example, man and stone. But a circle, although it cannot exist except in sensible matter, nevertheless sensible matter does not enter into its definition–and such are all **mathematical** things, as for example, numbers, magnitudes and figures.

3. But there are certain things which do not depend upon matter either in their existence or in their definition. This is because either they are **never** in matter–as is the case with God and the other separated substances–or because they are **not universally** in matter–as is the case with substance, potency and act, and being itself.

Concerning the latter, therefore is **Metaphysics** (3). But concerning those things which depend upon sensible matter according to existence but not according to definition is **Mathematics** (2). Concerning those things which depend upon matter not only according to existence, but also according to reason, is **Natural Science**, called **Physics** (1).

The subject of natural science

Since we are studying natural science, it is necessary to begin by assigning its **matter** or **subject**. Since whatever has **matter** is mobile or changeable, it follows that "**mobile being**" is the subject of natural science.

Natural science [or philosophy] is about natural things. What are natural things? Natural things are things whose principle, or source of activity, is their own intrinsic nature, as opposed to **artificial** things, which have the actions **we** give them. **Nature**, as we shall see, is defined as "the principle of motion and rest in that in which it is". Therefore, natural science is of those things which have within themselves

the principle of motion.

The division of natural science

Whatever is **common** to a whole group of things should be treated first and distinctly, and then one can go on to add what is **peculiar** to different species within the group. Therefore, just as for all the sciences of different types of **being** there is a first science which treats of **being in common**, namely first philosophy [or metaphysics], so too for all the sciences which treat of the different types of **mobile being**, it is fitting that there be a first science which treats of mobile being in common, and this is the *Physics*. Aristotle's works thus treat of:

–mobile being in common: *Physics*

–mobile being specifically:

–according to **local** motion: *On the heavens* (cosmology)

–according to motion to **form**:

–the elements:

–as to their transmutations in common: *Generation and corruption* (chemistry)

–as to special transmutations: *Meteorology*

–the compounds:

–inanimate: *Minerals* (chemistry cont.)

–animate: *The soul* (biology) & his many books on animals, sensation and other activities.

Methodology

Aristotle lays down two things in relation to the **order of procedure** in natural science:

- One must begin from the consideration of **principles**;
- Among principles, one must begin from the **more general**.

Beginning from principles

All science is from a knowledge of **causes**, since it is by virtue of knowing the cause that one is able to see and explain why a certain **conclusion** is true.

Likewise the **definition** of the subject, which is the middle term in proving the conclusion, is a statement of the **causes** of the thing.

Hence we have Aristotle's statement in the *Posterior Analytics*, Book 1, that "a complete definition is a demonstration differing only as to format". In other words:

- whereas in a **demonstration** one may use one cause to demonstrate another as, for example, proving from the **purpose** of a boat, which is to float [final cause] that one must use a certain **material**, such as caulking compound [material cause] to make it watertight,
- in a complete **definition** all four causes are aligned one after the other on the same level–as if one were to define a boat as "a sea-going construction [formal cause] made by man [efficient cause] out of water-resistant materials [material cause] for the sake of making it seaworthy [final cause]".

Going from the more generic to the specific, there is the following sequence: **principle, cause, element**. Thus:

- An **element** is "the primary things **out of which** a thing is composed, and is **in** it" (cf. *Metaphysics*, V) –such as the letters of a word, but not the syllables.
- A **cause** is "that from which something comes, **with dependence in being or in becoming**" –Thus things which are **outside** of a thing, or are not its primary components, may be causes, though not elements.
- A **principle** "that from which something comes **in any way**". Thus something is able to be a

"principle" without being a cause, as the starting-point of a motion.

These terms are sometimes applied to different causes from which demonstrations are made in the various sciences:

- "Principle" –to the moving/ agent/ efficient cause, where especially there is an order of proceeding.
- "Cause" –to formal and final causes, from which a thing especially depends for its being and becoming.
- "Element" –properly to the first material causes.

Not all the sciences demonstrate through all the causes:

- Mathematics –uses only the formal cause.
- Metaphysics –uses the formal and final causes principally, but also the efficient.
- Natural science –uses all the causes.

Beginning from more general principles

An argument why we must begin so:

Whereas to proceed in knowing from what is better known to us to what is better known by nature, is natural for us,

And whereas confused, universal things are better known to us,

Therefore we must proceed from the more universal to the singular [i.e. the specific].

The **major** proposition is based on the fact that since the things best known by nature [i.e. the most immaterial things] are less known to us, and since we proceed from things we know to things we do not, therefore we must go from things which are better known to us to the things which are better known by nature.

The implication is that things which are better known **by nature** are absolutely better known. Why should this be held? It is held because the degree of **knowability** depends upon the degree of **being** of that which is known, and this in turn depends on the degree of **actuality** of the thing. Whence those things which are most in **act** are most **knowable**.

Since whatever is **material** is to that extent **potential** [to any form], it follows that to the extent that something is separated from matter, or **immaterial**, to that extent it will be more **actual**, and thereby more **knowable** in itself.

Our knowledge, however, begins from material, sensible things, which are more known **to us**, but less knowable **in themselves**. Such things are intellectually knowable only in potency, until by abstraction they are divested of their individual matter [quantitatively "marked"]. At this time they become intellectually **knowable** [through the action of the agent intellect] and then [by being imprinted upon the possible intellect] actually **known**. There are thus three stages in the intellectual knowledge of a material thing:

1. A material thing is actually knowable to the **senses**, which receive the imprint of the sensible form united to matter, but only **potentially** knowable to the intellect, since the thing is in a singular material state.
2. The form of the material thing received by the senses is, through the action of the **agent** intellect, divested of individual material characteristics and rendered intellectually **knowable**.
3. This intellectualized form is now imprinted upon the **possible** intellect, and becomes intellectually **known**.

It is clear, therefore, that our knowledge, even of material things by the intellect, is only progressively actualized from potency to act.

Those things are more known absolutely which are more known in themselves. But those things are more known in themselves which have more of being–since each thing is knowable in so far as it is being. But those things are more beings which are more in act–whence such things are most knowable by nature.

But the opposite occurs with us, by virtue of the fact that we proceed in intellectual knowledge from potency to act, and the beginning of our knowledge is from sensible things, which are material and intelligible in potency–whence these are known to us prior to separated substances, which are more known according to nature, as is evident in *Metaphysics* II.

Now Aristotle says both "better known and more certain", since in the sciences there is not sought any kind of knowledge, but **certitude**.

As to the **minor** proposition, by "confused" is meant things which contain within themselves some things in potency and indistinctly. And since to know something indistinctly is mediate between pure potency and perfect act, therefore when our intellect proceeds from potency to act, that occurs to it first which is confused before that which is distinct. But science is then complete in act when one arrives by means of resolution at the distinct knowledge of principles and elements. And this is the reason why "confused" things are prior known to us before "distinct".

Why are the universals which the intellect knows, initially called "confused"? They are called thus simply because they are generic and contain their species only in potency. One "clarifies" them by arriving at the clear knowledge of the species at first only potentially present:

> Now that the universals are confused is plain, since universals contain within themselves their species in potency–and whoever knows something in a universal way, knows it indistinctly. But its knowledge then becomes distinct when each of those things which are contained in potency in the universal, are known in act–for he who knows "animal" knows "rational" only in potency. But one knows something in potency prior to knowing it in act. According, therefore, to that order of learning by which we proceed from potency to act, "animal" is known by us prior to knowing "man".

The statement that we known universals before singulars appears to contradict another statement of Aristotle in *Posterior Analytics*, Book 1, to the effect that singulars are better known to us, but universals by nature or absolutely so. This difficulty is explained simply by recognizing that in that particular passage Aristotle is talking about **sensible** singulars known by sense knowledge as prior to **intelligible** universals known by the intellect, and which, as abstract from matter, are more knowable in themselves. In the present case Aristotle is talking of the progress of knowledge **in the intellect**, from universal or generic knowledge to knowledge of the "singular", by which is here meant the **species**. Species, as having more of form, are by comparison with genera, more known:

> It should be understood that Aristotle in the *Posterior Analytics* takes as singulars the very sensible individuals. These are more known to us, since for us sense knowledge, which is of singulars, precedes intellectual knowledge, which is of universals. But since intellectual knowledge is more perfect–universals being intelligible in act, but not material singulars–universals are more known absolutely and according to nature.
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> But here in the *Physics*, by "singulars" Aristotle does not mean the individuals, but the species–which are more known according to nature, as having more perfect existence and distinct knowledge. But genera are prior known to us, by a knowledge that is in potency and confused.

Three signs also indicate that we must begin from more general principles.

1. Just as a **sensible whole**, such as a house, is seen by us prior to distinct knowledge of its parts, so in the intellect the generic universal is known before the perception of its species.
2. Just as an **intelligible whole** contains the parts of its definition in potency, and they are made actual by the definition, so too the universal is known before its species. Thus one knows man vaguely before recognizing "animal" and "rational" as its defining parts.

This seems to contradict the tenet that one knows the generic "animal" before the specific "man"; actually one does, but not as a part of the definition of man. Thus one has first the generic idea "animal", then a more specific idea "man", then a still more specific idea of "animal" and "rational" as the defining

parts of man.

3. **More universal sensible things** are first known: Seeing someone come from a far off **place**, we first recognize "animal", then "man", then "Socrates". Likewise in the order of **time**, a child sees his father first as a "man", then as "Plato"; hence the observation that "a child begins by calling all men 'father'". From this it is clear that we first know something confusedly before we know it distinctly.

CHAPTER 2
THE SUBJECT AND PRINCIPLES OF NATURAL SCIENCE
(Book 2, Lessons 1-4)

After the determination of the principles of **natural things**, namely subject, form and privation, Aristotle turns to the determination of the subject and principles of **natural science**. What are they? In any science it is necessary to know its **subject** and the **middle term** through which it demonstrates. Consequently, the first thing to be treated in this respect is the **subject** of natural science.

The definition of nature

Since the subject-matter of natural science is mobile being, which is equivalent to the world of nature, it is necessary to begin by defining nature.

Among the things around us, we say that some are "natural", while others are "artificial", or else they are designated in some other way, such as they are the result of "chance".

We call animals "natural", also plants and elements. What is the common note in all these, that is implied in our calling them "natural"? It is that they have **within** themselves some **principle of motion and rest**, whether this motion is growth, or local motion, or qualitative change.

Artificial things do not have as such a principle of motion within themselves, but only that of the natural substances which compose them. Thus a car does not move of itself, but by reason of distinct, independent parts which compose it, reacting to the combustion of fuel.

This principle of motion **in** natural things may be either **active** or **passive**. Thus fire burns actively, while a body attracted by a magnet is moved passively. It is an intrinsic ability to act or to be acted upon. Gravitational motion also is passive, but comes from active principles:

> For gravity in earth is not a principle ordained to its moving actively, but rather that it be moved–since just as other accidents follow upon substantial form, so also does place, and consequently being moved to a place, not however in such a way as for the natural form to be the mover, but the mover is the generator which gives such a form, upon which such a motion follows.

Since natural things differ from the non-natural by virtue of having their principle of motion **within** themselves, it is possible to arrive at the following definition:

> **Nature** is **the principle of motion and rest in that in which it is primarily and per se and not according to accident.**

- "Principle": This principle whence motion originates either actively or passively is found in living things when one thing gives birth to or generates another. Hence the word "nature" is from the Latin *nasci, natum*, "to be born"; Greek Φυσις comes from Φυ- "to sprout". Nature, as form, is sometimes a cause in the active sense of acting on another, sometimes in the passive sense of initiating self-motion, as in the case of gravity. Matter it is a cause in the passive sense of receiving motion, either from the form [natural motion] or from without [violent or para/supra-natural motion].
- "Of motion and rest": Just as nature designates the principle which causes something to move to a certain place, as in the case of gravity, so also nature is the principle of remaining at rest in its proper place when it reaches it.
- "In that in which it is": In distinction from artificial things, like machines, which do not have a nature of their own and only have the nature of their natural components, nature is **in** natural things.

- "Primarily": Thus in composite things, even though natural, one must distinguish between what is generic or remote and what is proper to the nature in question. For example, when an animal falls, it is not because of its nature as **animal**, but because of the generic nature of the **matter** out of which it is composed.

- "Per se and not according to accident": Thus when a doctor cures himself, the active principle of his cure is within himself, but only accidentally: The patient as patient has within himself only the ability **to be cured**, not the active ability to **cure**, as a doctor has. In all **artificial** things, the active principle is from without, as in the case of a house or a table.

The existence of nature is not demonstrated, but is self-evident. It is plain to the senses that there are many things which have the principle of their motion within themselves, i.e. are from nature. To try to prove the existence of nature is to try to prove the self-evident by something something that is less evident: the more known by the less known. However, **what** the nature of each thing is, or **what** is the principle of its motion, is not immediately clear and evident. Thus we can know that there is a principle of motion within something without knowing what it is.

The different senses of nature

Matter as nature

For the first natural philosophers, who had not yet arrived at the concept of prime matter, the basic matter of all things was some sensible body such as fire or air or water. Consequently, since all forms came to matter already in existence, they were in the order of accident, as with the forms of artificial things. The basic substantial elements might be either one or more than one. Empedocles, for example, proposed what became the traditional four: air, earth, fire and water.

Not only were these material elements the substance of things, but also they were perpetual and incorruptible, while the succeeding accidental forms they received came and went.

This opinion was true in that it considered matter as the subject and a constitutive part of natural things, but it was false in considering matter the whole substance. For them, there was no natural unit beyond the elements.

Form as nature

Actually a thing does not come into being until it receives a certain form. It is the form which gives it identity and actuality. We do not call something which is only potential by the name of that which is actual; we do not call a piece of lumber chair when it is potentially a chair, but only when it is actually a chair.

Matter is nature, and form is nature, yet the **composite** is not properly called nature, since it is the product of nature. That is because nature is a principle, and the composite is an effect or product of the principles. [Elsewhere in a secondary or loose sense, Thomas sometimes uses the word "nature" as equivalent to "essence", which is the composite of matter and form. Another equivalent word is "substance", which is the composite as the subject of accidents.]

Since the identity of a thing comes more from its act than from its potency, the word nature applies more to the **form** than to the **matter**.

How natural science differs from mathematics

We have seen in Chapter 1 that while natural science abstracts from matter in its individuality, mathematics abstracts from the aspects of matter that are proper to the different senses, such as sound, colour, smell and hardness.

> It is plain that posterior things are not comprised in the understanding of prior things, but conversely: whence the prior may be understood without the posterior, and not conversely. Thus it is evident that "animal" is prior to "man", and "man" is prior to "this man"–for man is in addition to animal, and this man is in addition to man. And because of this, "man" is not comprised in the understanding of "animal", nor "Socrates" in the understanding of "man"–whence animal may be understood without man, and man without Socrates and other individuals. And this is to abstract the universal from the particular.
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> Likewise among all the accidents which come to substance, first there comes to it **quantity**, and then the sensible **qualities** and actions and passions and the motions following upon sensible qualities. Thus quantity does not comprise in its understanding sensible qualities or passions or motions; nevertheless it does comprise in its understanding **substance**. Therefore quantity may be understood without matter subject to motion and sensible qualities, nevertheless not without substance. And therefore such quantities and whatever occurs to them are according to understanding abstracted from motion and sensible matter, but not from intelligible matter, as is stated in *Metaphysics* VII.
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> Since, then, they are so abstracted from motion according to understanding that they do not comprise in their understanding sensible matter subject to motion, the mathematician is therefore able to abstract them from sensible matter. And it makes no difference as to the truth of the consideration whether they be considered in this way or that. For although they are not abstracted as to their being, nevertheless the mathematicians, who abstract them according to understanding, do not lie–since they do not assert them to exist outside of sensible matter, for this would be a lie. But rather they consider them without considering sensible matter, which may be done without untruth–just as one may consider "whiteness" without "music", and truly so, even though they should co-exist in the same subject. But it would not be a true consideration if one should assert that "white" is not "musical".

By virtue of the failure to recognize that things which may be **understood** apart, i.e. abstracted, do not necessarily **exist** apart, the Platonic school conceived of both types of abstraction as actual categories of being. According to Plato, in addition to individual men, there exists a universal man, called an "idea"; likewise, in addition to sensible bodies, there exist mathematical bodies devoid of any sensible qualities.

Although the concept of material body does not involve singular material characteristics, it does nevertheless involve universal material characteristics, and as such stands for the individual material body–but there is no individual body corresponding to a universal body conceived as devoid of sensible characteristics.

The mathematician, whose subject matter is the odd and even, straight and curved, number, line and figure etc., defines without motion and matter. Not so with the natural scientist: his definitions, such as those of flesh, bone, man etc., comprise sensible matter.

The mixed sciences

The mixed, or intermediate, sciences are those which take their **principles** from purely mathematical sciences, and apply them to sensible **matter**. For example, perspective (in painting or architecture) applies to visual lines what geometry demonstrates concerning abstract lines; music applies to sounds what arithmetic considers concerning numerical proportions; astronomy applies both arithmetic and geometry to the heavens.

These sciences, even though their principles are derived from mathematics, nevertheless are considered more natural than mathematical. Why? The reason is because things have their determination from their term, and the term of these mixed sciences is natural things.

In this respect they are the converse of the purely mathematical sciences, for these begin from sensible matter and terminate in the abstract. The mixed sciences begin from the abstract and terminate in sensible matter. Because of this application on the part of the mixed sciences, it is plain that the purely mathematical sciences must abstract from sensible matter.

Since, however the mixed sciences are not purely natural, they will demonstrate their conclusions by another middle term than the natural sciences. Thus, whereas the natural scientist will demonstrate the sphericity of the earth from the properties of the matter composing it, i.e. by virtue of all its parts tending to the centre, the astronomer will do so, for example, from the shape of a lunar eclipse, or from the fact that the same stars are not seen from every part of the earth. [Most modern physics is "mixed science"].

Natural science considers both matter and form

Since both matter and form are nature, as principles of motion and rest, natural science treats of both. This is in contrast to the first natural philosophers who thought of nature primarily in terms of **matter**, [and to the tendency of some modern scientists to restrict their consideration to the quantifiable or measurable aspect of things.]

That it is necessary to consider form equally with matter may be seen from all the **arts**, where both are considered: the builder considers his materials in view of the form of the building; the doctor considers medicine in view of the health he wishes to attain. Since the arts imitate nature, the same importance of form must be true of nature.

Another reason why natural science considers both form and matter is the fact that form is the **end** of matter. In effect, the final form intended dictates what will be done to the matter. Thus in the arts, the one who designs the form of a ship specifies what the matter shall be. The form of the ship induced into the matter is the **end** of the construction of the ship; ultimately the **use** of the ship determines the form, and the form determines the matter.

The limit of natural science

Natural science considers "nature", "form", "cause" etc. only in so far as these exist in matter. To consider them absolutely, i.e. indifferently whether they exist in matter or are immaterial, belongs to metaphysics or "first philosophy". Aristotle uses the comparison of a doctor and sinews: the doctor does not consider the sinew as such–since this belongs to the natural scientist–but only in so far as it pertains to health; so the natural scientist considers the forms of things only as they are in matter.

The limit of the consideration of natural science is, therefore, those forms which in a certain way are separated from matter, but still have their being in matter, namely, rational souls. These are separated in that the intellective power is not the act of any corporeal organ, but are in matter in that they give natural being to the body they inform.

The consideration of forms totally separated from matter, however, and even of the rational soul in the state of separation from the body, pertains to first philosophy.

CHAPTER 3
THE PRINCIPLES OF NATURE

THOMAS AQUINAS TO BROTHER SYLVESTER

1. Since some things can be, although they are not, and some things now are; those which can be and are not are said to be potency, but those which already exist are said to be in act. But existence is twofold: one is essential existence or the **substantial** existence of a thing, for example man exists, and this is existence *simpliciter*. The other is **accidental** existence, for example man is white, and this is existence *secundum quid*.

2. Moreover, for each existence there is something in potency. Something is in potency to be man, as sperm or the ovum, and something is in potency to be white, as man. Both that which is in potency to substantial existence and that which is in potency to accidental existence can be called **matter**: for example sperm is the matter of man and man is the matter of whiteness.

3. But these differ, because that which is in potency to substantial existence is called the **matter from which**, but that which is in potency to accidental existence is called the **matter in which**. Again, properly speaking, that which is in potency to substantial existence is called **prime matter**, but that which is in potency to accidental existence is called the *subject*. Thus we say that accidents are in a subject; but we do not say that the substantial form is in a subject.

4. In this way matter differs from subject because the subject is that which does not have existence by reason of something which comes to it, rather it has **complete** existence of itself (*per se*); just as man does not have existence through whiteness. But matter has existence by reason of what comes to it because, of itself, it has **incomplete** existence. Hence, simply speaking, the form gives existence to matter; the accident, however, does not give existence to the subject, rather the subject gives existence to the accident; although sometimes the one is used for the other, namely matter for subject and conversely.

5. But, just as everything which is in potency can be called matter, so also everything from which something has existence whether that existence be substantial or accidental, can be called form; for example man, since he is white in potency, becomes actually white through whiteness, and sperm, since it is man in potency, becomes actually man through the soul. Also, because form causes existence in act, we say that the form is the act. However, that which causes substantial existence in act is called **substantial form** and that which causes accidental existence in act is called **accidental form**.

6. Because generation is a motion to form, there is a twofold generation corresponding to this twofold form. Generation *simpliciter* corresponds to the substantial form and generation *secundum quid* corresponds to the accidental form. When a substantial form is introduced we say that something comes into being *simpliciter*, for example we say that man comes into being or man is generated **[something]**. But when an accidental form is introduced, we do not say that something comes into being *simpliciter*, but that it comes into being as this; for example when man comes into being as white, we do not say *simpliciter* that man comes into being or is generated, but that he comes into being or is generated as white **[somehow]**.

7. There is a twofold corruption opposed to this twofold generation: *simpliciter* and *secundum quid*. Generation and corruption *simpliciter* are only in the genus of substance, but generation and corruption *secundum quid* are in all the other genera. Also, because generation is a change from non-existence to existence, contrarily, corruption should be from existence to non-existence. However, generation does not take place from just any non-being, but from the non-being which is being in potency; for example a statue comes to be from bronze which is a statue in potency and not in act.

8. In order that there be generation three things are required: **being in potency** which is matter, **non-existence in act** which is privation, and **that through which something comes to be in act** which is form. For example when a statue made from bronze the bronze which is in potency to the form of the statue is the **matter**; the shapeless or undisposed something is the

privation; and the shape because of which is called a statue is the **form**. But it is not a substantial form because the bronze, before it receives the shape, has existence in act and its existence does not depend upon that shape; rather it is an accidental form, because all artificial forms are accidental. Art operates only on that which is already constituted in existence by nature.

9. Therefore there are three principles of nature: matter, form and privation. One of these, form, is that by reason of which generation takes place; the other two are found on the part of that from which there is generation. Hence matter and privation are the same in subject but they differ in definition, because bronze and what is shapeless are the same before the advent of the form; but for one reason it is called bronze and for another reason it is called shapeless. Wherefore, **privation** is not said to be a *per se* principle, but rather a *per accidens* principle; because it is coincident with matter. For example we say that it is *per accidens* that the doctor builds, because he does not do this in so far as he is a doctor but in so far as he is a builder, which is coincident with being a doctor in the same subject.

10. But there are two kinds of accidents: the necessary, which is not separated from the thing, for example risible in man; and the non-necessary, which can be separated, for example white from man. Thus, although privation is a *per accidens* principle, still it does not follow that it is not necessary for generation, because matter is never entirely without privation. For in so far as it is under one form it has the privation of another and conversely, just as there is the privation of fire in air and the privation of air in fire.

11. Also, we should note that, although generation is from non-existence, we do not say that negation is the principle but that privation is the principle, because negation does not determine a subject. **Non-seeing** can be said even of non-beings, for example we say that the dragon does not see and we say the same of beings which are not apt to have sight, as stones. But privation is said only of a determined subject in which the habitus is apt to come to be; for example blindness is said only of those things which are apt to see. Also, because generation does not come to be from non-being *simpliciter*, but from the non-being which is in some subject, and not in just any subject, but in a determined subject, because fire does not come to be from just any non-fire, but from such non-fire as is apt to receive the form of fire; therefore we say that privation is the principle, and not negation.

12. Privation differs from the other principles, because the others are principles both in existence and in becoming. For in order that a statue come to be, it is necessary that there be bronze and, further, that there be the shape of the statue. Again, when the statue already exists, it is necessary that these two exist. But privation is a principle in **becoming** and not in existing, because until the statue comes to be it is necessary that it not be a statue. For, if it were, it would not come to be, because whatever comes to be is not, except in successive things, for example in time and motion. But from the fact that the statue already exists, the privation of statue is not there, because affirmation and negation are not found together, and neither are privation and habitus. Likewise, privation is a *per accidens* principle, as was explained above, but the other two are *per se* principles.

13. Therefore, from what was said, it is plain that **matter** differs from form and from privation by definition. Matter is that in which the form and privation are understood, just as in bronze the form and that which is shapeless is understood. Still, "matter" sometimes designates privation and sometimes does not designate privation. For example, when bronze becomes the matter of the statue, it does not imply a privation because when I speak of bronze in this way I do not mean what is undisposed or shapeless. Flour, on the other hand, since it is the matter with respect to bread, implies in itself the privation of the form of bread, because when I say "flour" the lack of disposition or the inordination opposed to the form of bread is signified. Also, because in generation the matter or the subject remains, but the privation does not, nor does the composite of matter and privation; therefore that matter which does not imply privation is permanent, but that which implies privation is transient.

14. We should notice, too, that some matter has a composition of form, for example bronze. For, although it is the matter with respect to the statue, the bronze itself is composed of matter and form. Therefore bronze is not called prime matter, even though it has matter. However,

that matter which is understood without any form and privation, but rather is subject to form and privation, is called prime matter by reason of the fact that there is no other matter before it. This is also called *hyle*, [which means chaos or confusion in Greek]. Also, because all knowledge and every definition comes by way of the form, prime matter cannot be defined or known in itself but only through the composite; consequently it might be said that that is prime matter which is related to all forms and privations as bronze is to the statue and the shapeless; and this is called first *simpliciter*. A thing can also be called prime matter with respect to some genus, as water with respect to aqueous solutions; this, however, is not first *simpliciter* because it is composed of matter and form. Hence it has a prior matter.

15. Note, also, that prime matter, and likewise form, is neither generated nor corrupted, because every generation goes from something to something. But that from which generation takes place is matter, and that in which generation terminates is form. Therefore, if matter and form were generated, there would be a matter of matter and a form of form, and so on *ad infinitum*. Hence, properly speaking, there is generation only of the composite.

16. Again, notice that prime matter is said to be numerically one in all things. But to be numerically one can be said in two ways: that which has a determined numerically one form, as Socrates; prime matter is not said to be numerically one in this way, since it does not have in itself a form. Also, something is said to be numerically one because it is without the dispositions which would cause it to differ numerically; prime matter is said to be numerically one in this way, because it is understood without all the dispositions which would cause it to differ numerically.

17. Notice, likewise, that, although prime matter does not have in its definition any form or privation, – for example neither shaped nor shapeless is in the definition of bronze, – nevertheless, matter is never completely without form and privation, because it is sometimes under one form and sometimes under another. Moreover, it can never exist by itself; because, since it does not have any form in its definition, it cannot exist in act, since existence in act is only from the form. Rather it exists only in potency. Therefore whatever exists in act cannot be called prime matter.

18. From this it is plain, therefore, that there are three principles of nature: matter, form and privation. But these are not sufficient for generation. What is in potency cannot reduce itself to act; for example, the bronze which is in potency to being a statue cannot cause itself to be a statue, rather it needs an **agent** in order that the form of the statue might pass from potency to act. Neither can the form draw itself from potency to act. I mean the form of the thing generated which we say is the term of generation, because the form exists only in that which has been made to be. However, what is made is in the state of becoming as long as the thing is coming to be. Therefore it is necessary that besides the matter and form there be some principle which acts. This is called the efficient, moving or agent cause, or that whence the principle of motion is. Also, because, as Aristotle says in the second book of the *Metaphysics*, everything which acts acts only by intending something, it is necessary that there be some fourth thing, namely, that which is intended by the agent; and this is called the end.

19. Again, we should notice that, although every agent, both natural and voluntary, intends an **end**, still it does not follow that every agent knows the end or deliberates about the end. To know the end is necessary in those whose actions are not determined, but which may act for opposed ends as, for example, **voluntary** agents. Therefore it is necessary that these know the end by which they determine their actions. But in natural agents the actions are **determined**, hence it is not necessary to choose those things which are for the end. Avicenna gives the following example. A harpist does not have to deliberate about the notes in any particular chord, since these are already determined for him; otherwise there would be a delay between the notes which would cause discord. However, it seems more reasonable to attribute deliberation to a voluntary agent than to a natural agent. Thus it is plain, by reasoning *a maiori*, that, if a voluntary agent, for whom deliberation is more proper, sometimes does not deliberate, therefore neither does the natural agent. Therefore it is possible for the natural agent to intend the end without deliberation; and to intend this is nothing else than to have a natural inclination to something.

20. From the above it is plain that there are four

causes: material, efficient, formal and final. But, although **principle** and **cause** are used convertibly, as is said in the fifth book of the *Metaphysics*, still, in the *Physics*, Aristotle gives four causes and three principles; because he takes as causes both what is extrinsic and what is intrinsic. Matter and form are said to be intrinsic to the thing because they are parts constituting the thing; the efficient and final causes are said to be extrinsic because they are outside the thing. But he takes as principles only the intrinsic causes; privation, however, is not listed among the causes because it is a principle *per accidens*, as was said.

21. When we say that there are four causes we mean the *per se* causes, to which all the *per accidens* causes are reduced, because everything which is *per accidens* is reduced to that which is *per se*.

22. And, although Aristotle calls intrinsic causes **principles** in the first book of the *Physics*, still **principle** is applied properly to extrinsic causes, as is said in the eleventh book of the *Metaphysics*; **element** is used for those causes which are parts of the thing, namely for the intrinsic causes; **cause** is applied to both. Nevertheless, one is sometimes used for the other: Every cause can be called a **principle** and every principle a **cause**.

23. However, **cause** seems to add something to **principle** as commonly used, because that which is primary, whether the existence of a posterior follows from it or not, can be called a **principle**, for example the manufacturer is called the principle of the knife because the existence of the knife comes from his operation. But, when something is moved from whiteness to blackness, whiteness is said to be the principle of that motion; and universally, everything from which motion begins is called a **principle**. However, whiteness is not that from which the existence of blackness follows. But cause is said only of that primarily from which the existence of the posterior follows. Hence we say that a cause that from whose existence another follows. Therefore that primarily from which motion begins cannot really be called a **cause**, even though it may be called a **principle**. Because of this, privation is placed among the principles and not among the causes, because privation is that from which generation begins. But it can also he called a *per accidens* cause in so far as it is coincident with matter, as was said above.

24. **Element**, on the other hand, is applied properly only to the causes of which the thing is composed, which are properly the materials. Moreover, it is not said of just any material cause, but of that one of which a thing is primarily composed; for example we do not say that the members of the body are the **elements** of man, because the members also are composed of other things; rather, we say that earth and water are the **elements**, because these are not composed of other bodies, but natural bodies are primarily composed of them.

25. Hence Aristotle says, in the fifth book of the *Metaphysics*, that an element is that of which a thing is primarily composed, which is in that thing, and which is not divided by a form. The explanation of the first part of the definition, "that of which a thing is primarily composed", is plain from the preceding. The second part, "which is in that thing", differentiates it from that matter which is entirely corrupted by generation; for example bread is the matter of blood, but blood is generated only by the corruption of bread. Thus bread does not remain in blood; and therefore bread cannot be called an element of blood. But the elements must remain in some way, since they are not entirely corrupted, as is said in the book *On Generation*. The third part, "and which is not divided by a form", differentiates an element from those things which have parts diverse in form, i.e., in species, as the hand whose parts are flesh and bone which differ according to species. An element is not divided into parts diverse according to species, rather it is like water whose every part is water. For an element to exist, it need not be undivided by quantity, rather it is sufficient that it be undivided by form. Even if it is in no way divided, it is called an element, just as letters are the elements of words. This it is plain from what was said that **principle**, in some way, applies to more than does **cause**, and **cause** to more than does **element**. This is what the Commentator says in the fifth book of the *Metaphysics*.

26. Now that we have seen that there are four genera of causes, we must understand that it is not impossible that the same thing have many causes, for example the statue whose causes are both the bronze and the artist: the artist is the efficient cause while the bronze is the material

cause. Nor is it impossible that the same thing be the cause of contraries; for example the captain is the cause of the safety of the ship and of its sinking. He is the cause of the latter by his absence and of the former by his presence.

27. Also, notice that it is possible that the same thing be a cause and the thing caused, with respect to the same thing, but in diverse ways; for example, walking is sometimes the cause of health, as the efficient cause, but health is the cause of the walking, as the end: Walking is sometimes on account of health. Also, the body is the matter of the soul, but the soul is the form of the body.

28. The efficient cause is called a cause with respect to the end, since the end is actual only by the operation of the agent. But the end is called the cause of the efficient cause, since the efficient cause does not operate except by the intention of the end. Hence the efficient cause is the cause of that which is the end, for example walking in order to be healthy. However, the efficient cause does not cause the end to be the end. Therefore it is not the cause of the causality of the end, i.e., it does not cause the end to be the final cause; for example the doctor causes health to actually exist, but he does not cause health to be the end

29. Also, the end is not the cause of that which is the efficient cause, but it is the cause of the efficient cause being an efficient cause; for example health does not cause the doctor to be a doctor – I am speaking of the health which comes about by the doctor's activity – but it causes the doctor to be an efficient cause. Therefore the end is the cause of the causality of the efficient cause, because it causes the efficient cause to be an efficient cause. Likewise, the end causes the matter to be the matter and the form to be the form, since matter receives the form only for the sake of the end and the form perfects the matter only through the end. Therefore we say that the end is the cause of causes, because it is the cause of the causality in all causes.

30. Also, we say that matter is the cause of the form, in so far as the form exists only in matter. Likewise, the form is the cause of the matter, in so far as matter has existence in act only through the form because matter and form are spoken of in relation to each other, as is said in the second book of the *Physics*. They are also spoken of in relation to the composite, as the part to the whole and as the simple to the composed.

31. But, because every cause, as cause, is naturally **prior** to that which it causes, notice that we say a thing is prior in two ways, as Aristotle says in book XVI of the *History of Animals*. Because of this diversity, we can call something prior and posterior with respect to the same thing, both the cause and the thing caused. We say that one thing is prior to another from the point of view of generation and time, and likewise from the point of view of substance and completeness. Since the operation of nature proceeds from the imperfect to the perfect and from the incomplete to the complete, the imperfect is prior to the perfect namely, from the point of view of generation and time, but the perfect prior to the imperfect from the point of view of substance. For example we can say that the man is before the boy according to substance and completeness, but the boy is before the man according to generation and time. But, although in generable things the imperfect is prior to the perfect and potency to act when we consider that in one and the same thing the imperfect is prior to the perfect and potency to act, still, simply speaking, the act and the perfect must be prior, because it is what is in act that reduces potency to act and it is the perfect that perfects the imperfect.

32. Matter is prior to form from the point of view of generation and time because that to which something comes is prior to that which comes to it. But form is prior to matter from the point of view of substance and completeness, because matter has completed existence only through the form. Likewise, the efficient cause is prior to the end from the point of view of generation and time, since the motion to the end comes from the efficient cause. But the end is prior to the efficient cause, in so far as it is the efficient cause, from the point of view of substance and completeness, since the action of the efficient cause is completed only through the end. Therefore these two causes, the material and the efficient, are prior by way of generation, but the form and the end are prior by way of perfection.

33. It must be noted that there are two kinds of necessity: absolute and conditional. **Absolute necessity** is that which proceeds from the causes prior by way of generation: the material and the efficient causes. An example of this is the

necessity of death which comes from the matter, namely the disposition of the composing contraries. This is called absolute because it does not have an impediment. It is also called the necessity of matter. **Conditional necessity**, on the other hand, proceeds from causes posterior in generation, namely, the form and the end. For example we say that it is necessary that there be conception if a man is to be generated. This is called conditional because it is not necessary simply that this woman conceive, but only conditionally, namely, if a man is to be generated. This is called the necessity of the end.

34. Notice, also, that three causes can coincide in one thing, namely, the form, the end and the efficient cause, as is plain in the generation of fire. Fire generates fire; therefore fire is the efficient cause in so far as it generates; also, fire is the formal cause in so far as it causes to exist actually that which before was in potency; again, it is the end in so far as the operations of the agent are terminated in it and in so far as it is intended by the agent.

35. But the end is twofold: the end of generation and the end of the thing generated, as is plain in the generation of a knife. The form of the knife is the end of generation; but cutting, which is the operation of the knife, is the end of the thing generated, namely, of the knife. Moreover the end of generation sometimes is coincident with the two aforementioned causes, namely, when generation takes place from what is similar in species, as when man generates man and the olive, an olive. But this cannot be understood of the end of the thing generated.

36. Notice, nevertheless, that the end coincides with the form in something which is numerically the same, because that which is the form of the thing generated and that which is the end of generation are the same numerically. But it does not coincide with the efficient cause in a thing numerically the same, but in a thing specifically the same, because it is impossible that the maker and the thing made be numerically the same, but they can be specifically the same. Thus, when man generates man, the man generating and the one generated are numerically diverse, but they are specifically the same. However, matter does not coincide with the others. This is because matter, by the fact that it is being in potency, has the nature of something imperfect; but the other causes, since they are in act, have the nature of something perfect. However, the perfect and the imperfect do not coincide in the same thing.

37. Therefore, now that we have seen that there are four causes, the efficient, formal, material and final, we must note that any of these causes can be spoken of in many ways. We call one thing a prior cause and another a posterior cause; for example we say that art and the doctor are the cause of health, but art is a prior cause and the doctor is a posterior cause; and it is similar in the formal cause and in the other causes. Notice, also that we must always bring the question back to the first cause. For example, if it be asked: "Why is this man healthy?", we would answer: "Because the doctor has healed him." Likewise, if it be asked: "Why did the doctor heal him?", we would say: "Because of the art of healing which the doctor has."

38. Notice, also, that the proximate cause is the same as the posterior cause and that the remote cause is the same as the prior cause. Hence these two divisions of causes into prior and posterior, remote and proximate signify the same thing. Moreover, it must be observed that that which is more universal is always called the remote cause, but that which is more particular is called the proximate cause. For example we say that the proximate form of man is his definition, namely, rational animal; but animal is more remote and substance is still more remote. All superiors are forms of the inferiors. Again, the proximate matter of the statue is bronze, but the remote matter is metal, and the still more remote is body.

39. Further, there is one cause which is a *per se* cause, another which is *per accidens*. A *per se* cause is said of one which is the cause of something as such, for example the builder is the cause of the house and the wood is the matter of the bench. A *per accidens* cause is said of one which happens to a *per se* cause. For example we say that the grammarian builds; the grammarian is called the cause of the building *per accidens*, not in so far as he is a grammarian, but in so far as it happens to the builder that he is a grammarian; and it is similar in other causes.

40. Likewise, some causes are simple, others are composed. A cause is simple when that alone is said to be the cause which is the *per se* cause, or that alone which is the *per accidens*

cause; as if we were to say that the builder is the cause of the house and likewise if we were to say that the doctor is the cause of the house. A cause is composed when both are said to be the cause, as if we were to say that the medical builder is the cause of the house.

41. According to the explanation of Ibn-Sînâ, that can be called a simple cause also which is a cause without the addition of another; for example bronze is the cause of the statue without the addition of another matter because the statue is made of bronze; and we say that the doctor causes health or that fire heats. But a cause is composed when many things must come together in order that there be a cause; for example not one man, but many are the cause of the motion of a ship; and not one stone, but many are the cause of a house.

42. Again, some causes are in act, others are in potency. A cause in act is one which causes a thing in act, as the builder while he is building or the bronze when a statue is made of it. A cause in potency is one which, although it does not cause a thing in act, can, nevertheless, cause it; as a builder when he is not building.

43. Note that, in speaking of causes in act it is necessary that the cause and the thing caused exist at the same time, so that if one exists the other does also. If there is a builder in act, it is necessary that he be building and, if there is building in act, it is necessary that there be a builder in act. But this is not necessary in causes which are only in potency.

44. Moreover, it should be noted that the universal cause is compared to the universal thing that is caused and the singular cause is compared to the singular thing that is caused, for example we say that a builder is the cause of a house and that this builder is the cause of this house.

45. Also, notice that, when we speak of intrinsic principles, namely, matter and form, according to the agreement and difference of things that are from principles and according to the agreement and difference of principles, we find that some are numerically the same, as are Socrates and this man – in the Socrates now pointed out; others are numerically diverse and specifically the same, as Socrates and Plato who, although they differ numerically, have the same human species; others differ specifically but are generically the same, as man and ass have the same genus animal; others are generically diverse and are only analogically the same, as substance and quantity which have no common genus and are only analogically the same, because they are the same only in so far as they are beings. "Being", however, is not a genus because it is not predicated univocally, but only analogically.

46. In order to understand this last we must notice something is predicated of many things in three ways: univocally, equivocally and analogically. Something is predicated **univocally** according to the same name and the same nature, i.e., definition, as animal is predicated of man and of ass, because each is called animal and each is a sensible, animated substance, which is the definition of animal. That is predicated **equivocally** which is predicated of some things according to the same name but according to a different nature, as dog is said of the thing that barks and of the star in the heavens, which two agree in the name but not in the definition or in signification, because that which is signified by the name is the definition, as is said in the fourth book of the *Metaphysics*. That is said to be predicated **analogically** which is predicated of many whose natures are diverse but which are attributed to one same thing, as health is said of the animal body, or urine and of food, but it does not signify entirely the same thing in all three; it is said of urine as a sign of health, of body as of a subject and of food as of a cause. But all these natures are attributed to one end, namely to health.

47. Sometimes those things which agree according to analogy, i.e., in proportion, comparison or agreement, are attributed to one end, as was plain in the preceding example of health. Sometimes they are attributed to one agent, as medical is said of one who acts with art, of one who acts without art, as a midwife, and even of the instruments; but it is said of all by attribution to one agent which is medicine. Sometimes it is said by attribution to one subject, as "being" is said of substance, quantity, quality and the other predicaments, because it is not entirely for the same reason that substance is being, and quantity and the others. Rather, all are called being in so far as they are attributed to substance which is the subject of the others.

48. Therefore being is said primarily of substance and secondarily of the others.

Therefore “being” is not a genus of substance and quantity because no genus is predicated of its species according to prior and posterior; rather, “being” is predicated analogically. This is what we mean when we say that substance and quantity differ generically but are the same analogically.

49. Therefore the form and matter of those things which are numerically the same are themselves likewise numerically the same, as are the form and matter of Tullius and Cicero. The matter and form of those things which are specifically the same and numerically diverse are not the same numerically, but specifically, as the matter and form of Socrates and Plato. Likewise, the matter and form of those things which are generically the same, as the soul and body of an ass and a horse differ specifically but are the same generically; likewise, the principles of those things which agree only analogically or proportionally are the same only analogically or proportionally, because matter, form and privation or potency and act are the principles of substance and of the other genera. However, the matter, form and privation of substance and of quantity differ generically, but they agree according to proportion only, in so far as the matter of substance is to substance, in the nature of matter, as the matter of quantity is to quantity; still, just as substance is the cause of the others, so the principles of substance are the principles of all the others.

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CHAPTER 4
CAUSAL EXPLANATIONS IN THE SCIENCE OF NATURE

Natural science seeks the causes of motion. These causes are found in the nature of things and in outside factors. One baffling question is whether everything that happens has a cause, since some things happen by chance, which seems to be the absence of any rational explanation or cause.

What is chance? (Book 2, Lessons 7-10)

Opinions on the subject

There are two opposite extremes among opinions regarding chance. The first is to deny chance altogether and attribute everything to **determined** causes. Thus if a man went to market to buy a suit and there met a debtor who paid him an old debt, this encounter is attributed to good luck–yet it had a determinate cause: the deliberate intention to buy a suit, which was also the cause of finding the debtor. Thus chance as a cause is fictitious.

The opposite opinion is that **everything** happens by chance: Aristotle states that certain men stated chance to be the cause of the heavens and of all the parts of the world. And they said that the revolution of the world and all the consequent seasons and happenings on this earth are from chance. Thus Democritus held that from the concurrence of atoms movable of themselves the heavens and the whole world were constituted by chance.

A third opinion makes chance a divine reason which we cannot understand, something like divine providence. But the arrangement of things by God cannot be called chance, since such events are reasoned and ordered.

Distinctions needed for defining chance

Some things happen always or regularly in the same way, while other things, like having six fingers, are exceptional. Chance is something that is exceptional to the rule; since such exceptions occur, it is not right to say that everything is determined.

Regularity is a characteristic of things that happen by nature, since nature always acts in the same way unless impeded. Human behaviour, coming from free, will is not necessarily regular, but the will, like nature, acts for a purpose, unlike what happens by chance. Chance results are unintended and unforeseen in the case of volitional acts, and exceptional in the case of natural causality; both the will and nature are accidental causes of what happens by chance.

Definition of chance

Chance may now be defined as: “the accidental cause of exceptional or unintended results of choice or nature acting for another purpose”. Thomas uses “chance” as a generic term, and “fortune” (or “luck”) for unintended results of human choice.

Chance and fortune are termed **good** or **bad** according to their effect on people. Also, just as chance applies to something that **happens** without being intended, it can likewise be applied to what does **not happen**, i.e. to missing what was intended, as when we say someone worked in vain.

To what genus of cause is chance reduced? Since it pertains to what happens by nature or by intellect (and will), and these are causes “whence comes the beginning of motion”, chance is reducible to the **efficient** cause.

Natural science demonstrates through all four causes (Book 2, Lesson 11)

Chapter 1 noted how all four causes apply to natural science, and Chapter 2 defined each of these causes. As for the **material** cause, a scientist may demonstrate that because something is composed of contraries it will necessarily corrupt. As for the **efficient** cause, a scientist may demonstrate that as the sun's position moves to the north the rainy season comes, but as it goes back south the dry season follows. But both material and efficient causes can be impeded from having their normal effects, and the presence of these causes does not necessarily demand that their effects follow.

The **formal** cause is used in a hypothetical demonstration stating: "If such-and-such a thing is to be produced, then such-and-such material is necessarily required." As for **final** cause, a natural scientist may demonstrate that something is so because that is **more fitting**, for example, "The front teeth are sharp because they are better thus for biting food, and nature does that which is better." Nevertheless this does not mean that nature always does what is better absolutely speaking, but as befits the substance or nature of each thing–otherwise it would give every animal a rational soul, since that is better than an irrational soul.

Nature acts for an end (Book 2, Lesson 12)

Nature is among the number of causes which act for the sake of something. And this is important with reference to the problem of providence. For things which do not know the end do not tend toward the end unless they are directed by one who does know, as the arrow is directed by the archer. Hence if nature acts for an end, it is necessary that it be ordered by someone who is intelligent. This is the work of providence.

Those who attack final causality reject the supposition that nature is always seen to do what is best and most fitting, e.g. that a foot is made the way it is for the sake of walking. Arguing against this they would say that the good or utility which comes about from an operation of nature simply **happens** (by chance), while the process itself is determined by the necessity of matter. Thus it is the necessity of matter whereby the sun's heat causes water to evaporate and become clouds, which later cool, condense and fall as rain. The rain may **happen** to fall on crops and help them grow, but it may equally well **happen** to fall on ripe grain and spoil it.

They argue the same way when speaking of the parts of animals: Front teeth were not made sharp and back teeth broad for the convenience of eating, but they simply **happened** that way and the utility followed.

To the objection that such usefulness follows always or for the most part, and as such must be intended by nature, they answer that in the beginning many non-viable forms came and went and only the fit survived.

> They state that in the foundation of the world the four elements came together to constitute natural things, and there were many and various dispositions of natural things. Now wherever everything came together in just the way that is suitable for some utility, as if they had been made for the sake of this, such things alone were preserved–since they had a disposition apt for preservation not from any agent intending an end, but from that which is "per se in vain", i.e. from chance. Whatever things did not have such a disposition were destroyed and do not exist today. Thus Empedocles stated that in the beginning there were certain beings generated which were part-oxen and part-men.

After stating this position (the essentials of later Darwinism) Aristotle gives several arguments against "natural selection by chance":

- What happens always or for the most part (regularly) is not from chance.
- Nature always acts as though for and **end**. This is clear from the similarity between nature and art;

just as art proceeds towards a definite end with determinate means, so does nature. Thus medicine tries to imitate natural processes.

- The purposiveness of nature is most evident in animal behaviour, such as the activity of spiders and bees, which appear so intelligent. Yet they do not act from intelligence, but through nature, as is evident from the fact that they always act in the same way. For every swallow makes its nest in a similar way, and every spider makes its web in a similar way–which would not be the case if they were acting from intellect and art, for every builder does not make a house in a similar way, since the artisan is able to decide on the form of the artifact and can vary it.

- The form of a new life is the **end** of generation, and the nature of an end is that other things be done for the sake of it. Therefore the process of generation is for the sake of an end.

In reply to objections against nature's acting for an end, Aristotle declares:

- The "sins of nature", such as monstrosities, are not evidence that nature is not purposeful, because (1) like art, the recognition of errors supposes that there is a right way for achieving a certain end. (2) The determined principles and determined order of development, as in the case of an embryo, indicate that nature acts for a determinate end. (3) Both animals and plants have their own specific seed to produce their like and not indiscriminate offspring.

- The **agent** and the **matter** are not sufficient reasons for the way a thing develops, because nature always proceeds from the same principle to the same end, unless there is some impediment. Just as when a man has a habit of going to a particular place at a particular time it is because of an abiding intention, such as to buy something, so the regularity of nature is for a specific purpose.

- The fact that nature does not **deliberate** is no argument that it does not act for a purpose, because even **art** does not deliberate.

  The artisan does not deliberate in so far as he possesses the art, but in so far as he fails from the certitude of the art–whence the most certain arts do not deliberate, as the writer does not deliberate as to how he should form the letters. Even those artisans who do deliberate, once they have found the certain principle of the art, do not deliberate in carrying it out. Thus the harpist, if he should deliberate before touching each string, would be considered most inexperienced.

  From this it is evident that not to deliberate occurs to some agents, not because they do not act for an end, but because they have determined means by which they act. Whence nature, since it has determinate means through which it acts, for this reason does not deliberate.

  For in no other respect does nature seem to differ from art except that nature is an intrinsic principle, and art is an extrinsic principle. For if the art of ship-making were intrinsic in the wood, the ship would be made by nature in the same way that it is now made by art...

  Whence it is evident that nature is nothing but a certain kind of art, i.e. the divine art, impressed upon things, by which these things are moved to a determinate end. It is as if the shipbuilder were able to give to timbers that by which they would move themselves to take the form of a ship.

CHAPTER 5
A PROPERTY OF MOBILE BEING: MOTION

Concepts involved in the discussion (Book 3, Lesson 1)

Motion is now the subject of discussion because **nature**, just discussed, is the principle of motion and change.

Because motion takes place over space and time, it is continuous. The **continuum**, defined according to resolution, is that which is "divisible to infinity"; according to composition, it is that "whose parts are joined at a common boundary".

Later there will be a discussion of the notion of **infinity**, likewise of the external measures of motion, which are **place** and its negative correlative **void**, and **time**.

To define motion will require reference to some basic concepts, first of all the division of all being by potency and act, secondly the division of being according to the ten genera or categories, which are here presupposed.

Thirdly, reference will be made specifically to the category of **relation**, which is always grounded on some other accident, chiefly **quantity** and **action**. For quantity may be a measure even of something external to it; while the agent transfuses its action into something other than itself.

Certain relations are founded upon quantity, especially upon that species of quantity which is number, to which the basic notion of measure pertains, as is evident in "double and half", "multiple and sub-multiple [fractions]" etc. Similarly "same", "like" and "equal" are founded upon unity, which is the principle of number.

Other relations are founded upon action and passion: either according to present act, as something is said to be "heating" in relation to that which is heated, or according to past act, as a father is referred to a son because he engendered him, or else according to future act, as a master is related to a servant because he is able to make him do something. All this is treated further in *Metaphysics* V.

The definition of motion, therefore, will involve the notions of potency and act (and therefore also of privation and possession) and the categories of substance, quantity, quality and location, which will be used to determine the species of motion. It will also involve the relationship between the thing being moved and the mover.

Definition of motion (Book 3, Lesson 2)

Some have defined motion by saying that motion is "a going-out from potency to act which is not sudden". But they are in error, because they have placed in the definition elements that are posterior to motion: for "going-out" is a species of motion;. "sudden", likewise, involves time in its definition, since "sudden" is what occurs in the indivisible of time [i.e. the instant]; time, however, is defined in terms of motion.

Consequently it is impossible to define motion in terms of what is prior and better known otherwise than the Philosopher here does. For every genus is divided by potency and act. Since these are among the first differences of being, they are naturally prior to motion, and it is these that the Philosopher uses to define motion.

Consider, therefore, that some things are in act only, some are in potency only, some others are midway between potency and act. What is in potency only is not yet being moved; what is already in perfect act

is not being moved but has already been moved. Consequently, what is being moved is midway between pure potency and act, which is partly in potency and partly in act–as is evident in alteration. For when water is only potentially hot, it is not being moved; when it has now been heated, the motion of heating is finished; but when it possesses some heat, though imperfectly, then it is being moved–for whatever is being heated gradually acquires heat step by step. Therefore this imperfect act of heat existing in a heatable object is motion–not, indeed, by reason of what the heatable object has already become, but in as much as, being already in act, it has an order to a further act. For should this order to a further act be taken away, the act already present, however imperfect, would be the term of motion and not motion itself–as happens when something becomes half-heated. This order to a further act belongs to the thing that is in potency to it.

Similarly, if the imperfect act were considered solely as ordered to a further act, under its aspect of potency, it would not have the nature of motion but of a principle of motion–for heating can begin from either a cold or a lukewarm object.

The imperfect act, therefore, has the character of motion both in so far as it is compared as potency to something more perfect, and as act to something less perfect.

Hence motion is neither the potency of a thing existing in potency, nor the act of a thing in act, but it is **the act of a thing in potency**, where the word "act" designates its relation to a prior potency, and the words "of a thing in potency" designates its relation to a further act.

Whence the Philosopher most aptly defines motion as **the act of a thing existing in potency in so far as it is in potency**.

This definition can be specified according to the different species of motion: thus **alteration** is the act of the alterable in so far as it is alterable; growth is the size of what is capable of growth in so far as it is capable of growth; locomotion is the localization of what can change place in so far as it is capable of changing place. Later we will see that generation and corruption are not, strictly speaking, motion.

- Motion is **act**: This is because that by which something previously existing in potency becomes actual is an act. But something becomes actual when it is being moved, although previously it was in potency. Therefore motion is an act. Thus when the construction of a building has already begun and is partly in act we say that a house is "being built". Before something is moved it is in potency to a perfect act which is the term of the motion, and to an imperfect act which is further motion.

- Motion is the act **of a thing existing in potency**: As an act, motion is found in its proper subject, which is something in potency. All bodily things are in act and in potency in different respects, and they subject to the action of one another; thus they both act and are acted upon. When such action is being received, in so far as the recipient is capable of receiving this action it it is in motion. Things in potency, whether they act or are acted upon, are moved, since when acting they are acted upon and when moving they are being moved. For most things to act upon another requires a self-actualization; thus they are "moved movers".

- Motion is the act of something in potency **in so far as it is in potency**: This phrase is necessary, because the act of something in potency can be static. The act is motion only in so far as the subject is capable of further act. Thus the shape of a half-carved statue is not motion unless it is the shape of the wood in so far as the wood is capable of further form. Besides, this phrase of the definition is the only way of distinguishing contrary motions, such as getting sick or getting well; the patient at this instant is as he is; we can only say he is on the road to recovery or is getting worse by reference to the term to which, in his actual state, he is in potency to.

Aristotle goes on [Thomas, lesson 3] to reject other definitions of motion, such as "otherness", "unequalness", or "non-being". Philosophers were led to these inadequate definitions because they were

struck by the **indeterminateness** of motion, as something incomplete and imperfect; so it seemed to belong to the genus of privation. The real reason why motion is indeterminate is that cannot be identified simply with either potency or act, but is something in between, as explained above.

5.3 Action and passion are the same motion (Book 3, lesson 4-5)

After defining motion, the Philosopher now shows whose act motion is, i.e. whether it is the act of the mobile or of the mover. Also he gives another definition of motion which is related to the previous one as material to formal and as a conclusion to its principle. And this is the definition: **motion is the act of the mobile in as much as it is mobile**. This definition is a conclusion from the previous one. For, since motion is "the act of a thing existing in potency in as much as it is in potency", and since that which exists in potency as such is the mobile and not the mover (for the mover as such is in act), it follows that motion is an act of the mobile as such.

The problem of whose act motion is arises because not only is the mobile in potency to being moved, but the mover is also in potency to moving the mobile, since a mover is not always actually moving something. Its moving something is concurrent to the mobile being moved, and its rest is concurrent with the rest of the mobile. Movers are moved when it is a question of being put in contact with the mobile, such as a saw to wood; they are also moved be reaction from the mobile, as when the blade grows dull.

Nevertheless, motion is essentially an act of the mobile and only accidentally an act of the mover, and if it is an act of the mover, that is in so far as the mover is itself mobile. This is clear also because the mover or agent normally has the actual developed form towards which the mobile is being moved; thus something hot causes heat, and animals beget their like.

On the other hand, the act of the mover is not distinct from the act of the mobile. Since motion is an act of the mobile it is somehow also an act of the mover, since what the mover causes by acting and what the moved receives in being acted upon are one and the same thing. Just as the same relationship differs according to term–thus two to one is double, while one to two is half–so motion, in so far as it proceeds from the mover to the mobile, is an act of the mover, but in as much as it is in the mobile from the mover, it is an act of the mobile.

An objection comes from the distinction between **action**, which is the act of the agent, and **passion**, which is the act of the patient. Both are motion, and are either (1) the same motion or (2) diverse motions. If they are diverse, then each of them must be in some subject. Either (a) both will be in the patient (the mobile) or (b) action will be in the agent and passion in the patient, since it would not make sense to say that passion is in the agent and action in the patient; nor (c) can we say that both are in the agent.

The case of (2b), that action is in the agent and passion in the patient, would require either that there be motion in every agent, since action is a kind of motion [then there could be no unmoved mover] or that the agent would have motion without being moved; both consequences are unreasonable.

The case of (2a) would mean that the patient has two motions; for example, both teaching and learning would be in the student, and that is nonsense. What is clear is that action and passion terminate at the same specific term; for what the agent does and what the patient receives are one and the same.

We are then faced with (1), that action and passion are one motion. This position has its own difficulties: It would reduce two specifically different things to one, namely, action which is an act of the agent, and passion which is an act of the patient. Thus teaching, which is ascribed to the teacher, would be the same as learning which is ascribed to the student. Moreover, if teaching is the same as learning then acting is the same as being acted upon; thus every teacher would be learning and every student teaching.

The answer to this problem is that action and passion are not two motions, but one and the same motion;

in so far as it is from the agent it is called "action", and in so far as it is in the patient it is called "passion". As for the difficulties raised, there is nothing wrong with an act of one thing being in something else, for teaching is an act of the teacher, an act continuing from the teacher into the student; this act which is the agent's in its source is the very one which is in the patient as received in him. But it would be wrong to say that the act of the one is the act of the other in precisely the same way.

Likewise, there is nothing to prevent one act from belonging to two things so long as it is one reality with two different aspects. Thus it is not necessary to say that a teacher is learning or a learner is teaching, because the same motion has different aspects, just as the road from Lagos to Ibadan is the same as the road from Ibadan to Lagos, but the direction one is going is all important and makes the concrete difference. The idea of motion abstracts from the fact that it is action or passion. The latter terms designate the same motion, but include two different real relations, to the source of the motion or to its term or recipient. These relations are the reason why action and passion are listed among the ten categories of real being.

Motion, being an imperfect reality, is placed reductively in that genus which terminates the motion (quality, quantity or location), as the imperfect is reduced to the perfect. But in regard to what reason apprehends about motion, namely that it is midway between two terms, there the notion of cause and effect are brought in; because for something to be reduced from potency to act an agent cause is required. From this aspect, motion pertains to the predicaments of "action" and "passion", for these two predicaments are based on the notions of an acting cause and of an effect.

In conclusion, we can say that motion is the act both of the mover and of the mobile. To give a specific example, we can say that building is the act of the builder and of the buildable in so far as each is capable of building or of being built.

Book 3, Lesson 5 *The Categories (Predicaments)*

Pertaining to essence . . . . . 1 Substance
Not of essence, but inhering:
- following upon matter . . . . . 2 Quantity
- following upon form . . . . . 3 Quality
- in respect to another . . . . . 4 Relation

Extrinsic:
- as caused:
  - Acted upon . . . . . 5 Passion
  - Acting upon other . . . . . 6 Action
- as measured:
  - by time . . . . . 7 When
  - by place:
    - as whole . . . . . 8 Where
    - as order of parts . . . . . 9 Posture
- as completing man . . . . . 10 Clothed

For the clarification of these points it must be noted that being is not divided univocally into the ten predicaments as genera are divided into species. Rather it is divided according to the diverse modes of existing. But modes of existing are proportional to the modes of predicating. For when we predicate something of another, we say this is that. Hence the ten genera of being are called the ten predicaments.

Now every predication is made in one of three ways. One way is when something pertaining to the essence is predicated of the same subject, as when I say Socrates is a man, or man is animal. The predicament of **substance** is taken in this way.

Another mode is when something not of the essence of a thing, but inhering in it, is predicated of a thing.

This is found either on the part of the matter of the subject, and thus is the predicament of **quantity** (for quantity properly follows upon matter–thus Plato also held the "great" to belong to matter), or else it follows upon the form, and thus is the predicament of **quality** (hence also qualities are founded upon quantity as colour is in a surface, and figure is in lines or in surfaces), or else it is found in respect to another, and thus is the predicament of **relation** (for when I say a man is a father, nothing absolute is predicated of man, but a relation which is in him to something extrinsic).

The third mode of predication is had when something extrinsic is predicated of a thing by means of some denomination. For extrinsic accidents are also predicated of substances; nevertheless we do not say that man is whiteness, but that man is white. However, to be denominated by something extrinsic is found in a common way in all things, and in a special way in those things which pertain only to man.

In the common way a thing is found to be denominated by something extrinsic either according to the intelligibility of a cause or of a measure. For a thing is denominated as caused and measured by something extrinsic. Now although there are four genera of causes, two of them are parts of the essence, namely matter and form. Hence a predication which can be made in respect to these two pertains to the predicament of substance, e.g., if we say that man is rational and that man is corporeal. But the final cause does not cause anything outside of the agent, for the end has the nature of a cause only insofar as it moves the agent. Hence there remains only the agent cause by which a thing can be denominated as by something extrinsic.

Therefore, insofar as a thing is denominated by the agent cause, there is the predicament of **passion**. For to be acted upon is nothing other than to receive something from an agent. And conversely, insofar as the agent cause is denominated by the effect, there is the predicament of **action**. For action is an act from the agent to another.

Furthermore some measures are extrinsic and some are intrinsic. Thus the proper length and breadth and depth of each thing is intrinsic. Therefore, a thing is denominated by these as by something inhering intrinsically. Hence this pertains to the predicament of quantity.

However time and place are extrinsic measures. Therefore, insofar as a thing is denominated by time, there is the predicament "**when**", and insofar as it is denominated by place, there are predicaments "**where**" and "**posture**" (*situs*), which adds to "where" the order of parts in place.

Now it was not necessary that this latter point be added in respect to time. For the order of parts in time is implied in the very meaning of time. For time is the number of motion in respect to before and after. Therefore, a thing is said to be "when" or "where" by a denomination from time or place.

However there is something special in men. For nature has adequately provided other animals with those things which pertain to the preservation of life, as horns for defence, and heavy and shaggy hides for clothing, and hoofs or something of this sort for walking without injury. And thus when such animals are said to be armed or clothed or shod, in a way they are not denominated by anything extrinsic but by some of their own parts. Hence in these cases this is referred to the predicament of substance, as, for example, if it were said that man is "handed" or "footed".

But things of this sort could not have been given to man by nature, both because they were not suitable for the delicacy of his make up and because of the diversity of the works which belong to man insofar as he has reason. Determinate instruments could not have been provided by nature for such works. But in the place of all of these things there is reason in man, by which he prepares for himself external things in the place of those things which are intrinsic in the other animals. Hence, when a man is said to be armed or clothed or shod, he is denominated by something extrinsic which has the nature neither of a cause nor of a measure. Hence there is a special predicament, and it is called "**being clothed**" (*habitus*).

But it must be noted that this predicament is attributed to other animals also, not insofar as they are considered in their own nature, but insofar as they come under the use of man, as when we say that a horse is decorated or saddled or armed.

CHAPTER 6
THE INFINITE

Infinity comes up for discussion at this point because it is related to the continuity of motion: A continuum is infinitely divisible. It also affects some basic conditions of motion, such as direction, diversity of elements etc. On the other hand, it is not a central discussion in the philosophy of nature.

Opinions of early philosophers (Book 3, Lesson 6)

- The Pythagoreans: The infinite is in sensible things extending beyond the heavens (= an infinite physical universe)
- Plato: The infinite is in the world of separated ideas.
- Anaxagoras: Since anything can come from anything, everything has infinitely divisible particles of every different thing, such as blood and bone; change is separating the parts out.
- Democritus: Particles are infinite and indivisible, differing only in figure.

Dialectical arguments for the existence of infinitude (Book 3, lesson 7)

- Time, it seems, has always existed.
- Any magnitude is infinitely divisible.
- If the world has always existed and will always exist, there is the generation and corruption of an infinite number of individuals.
- If everything is in a place, and place is an enclosing body, then everything must be bordered by another body *ad infinitum*.
- Number seems to be infinite, since the intellect can always add a new number without limit.

Distinctions concerning infinitude

Some clarification of the notion of infinitude is needed. The first is to distinguish between an infinite continuum and an infinite number of things.

Secondly, as a privative term it can have various meanings, just as "invisible can be said in three ways: 1) what is of its very nature not apt to be seen, for example, a sound which is not in the genus of visible things; 2) what is difficult to see, as what is seen in the dark or form a distance; 3) what is apt to be seen but is not, as something in total darkness. Likewise "infinite" (what cannot be crossed) can mean 1) what is outside the genus of traversable things, such as a point and a form; 2) what can be passed over but its passage is impossible or very difficult for us; in this way we say that the depth of the sea is infinite; 3) what is passable, but not to its end, such as a line without end or any other quantity without limits. This is the proper sense of the word "infinite".

Thirdly, we can talk of an actual infinite size or number, or a potential infinite: what can always be further divided or added to.

Finally, we can distinguish between metaphysical infinitude (such as that of God and his power etc.), abstract mathematical infinitude, and the infinitude of a sensible body. It is only the latter we are concerned with in this course.

Dialectical arguments against infinitude (Book 3, Lesson 8)

- It would seem that no body can be infinite, because it is limited by a surface, which must be finite, since it is expandable.
- It would seem that no infinite multitude, since if it can be numbered, whatever that number is, is finite.

- Every composite sensible body is made up of elements. If one of different kinds of elements is infinite, that would so dominate the whole that it would counteract any influence of the others, and thus destroy the equilibrium of the composite.
- The component elements of a body cannot be infinite, because each one of them would occupy all space, unless they were to interpenetrate, which is impossible.
- If any element were infinite, it would be impossible for the whole universe to be anything but that element, both because it would occupy all space and because it would overpower other elements, as Heraclitus says that at some future time all things will be converted into fire because of the excelling power of fire.
- (Lesson 9) A body of infinite size could either never be in motion or would always be in motion, since it would have no orientation of up or down, centre or edge, or any direction whatsoever, within or without itself.
- Were there to be motion of dissimilar parts (such as water and earth) within such a body, then the infinite whole would not be one body simply, but only a collection of contiguous bodies.
- There can be no infinite body without an infinite number of parts. They could be only of one kind, since that would destroy all competition.
- Every body is in a place, and place means being in some definite reference point to other bodies, up or down, right or left, as determined by gravitation to a place of rest. Such directional reference would be impossible in an infinite body.

The infinite as existing in potency (Book 3, Lesson 10)

The foregoing would indicate that there is no body of infinite size. On the other hand, some kind of infinitude must exist; otherwise time could not go on indefinitely (in an eternal world), and magnitudes would be divisible into parts that are not magnitudes because they are indivisible; likewise number could not increase indefinitely.

Therefore infinitude exists as something in potency, in the sense that every magnitude is always divisible and every number can be added to. But something is found to be in potency in two ways: In one way the whole can be reduced to act, as it is possible for this bronze to be a statue. But the infinite in potency is not meant ever to be entirely in act; rather it will be in act not all at once, but part after part. It is just as we say that today is actual, because one instant of this day is presently actual.

The infinitude of magnitudes and of numbers both consists in a finite actualization of something that can always be further actualized, by division or addition. But the two differ in that a magnitude that is divided or added to remains permanent and is not corrupted, but the finite parts of an infinite time and of successive generation are corrupted, while time and generation go on.

Definition of infinitude (Book 3, Lesson 11)

The **infinite** is *that beyond which there is always something*. This definition excludes a circle, which can be the subject of infinite motion, but the same parts are gone over again and again. It also excludes the definition of early philosophers, "that outside of which there is nothing", which is the definition of a perfect and whole thing. But the infinite, in as much as it is in potency, is like matter with respect to the perfection of magnitude, and like a whole in potency, not a whole in act. It is something imperfect, comparable to matter not having perfection. And, since the whole contains but matter is contained, the infinite as such does not contain but is contained, since whatever amount of the infinite is is in act is always contained by something greater, as it is possible to move to something beyond it.

From this, two other conclusions follow. One is that the infinite, as such, is unknown, because it is like matter without definition or form, and matter is not known except through form. The other conclusion is that the infinite has more the notion of a part than of a whole, since matter is compared to the whole

as a part. And it is not a surprise that the infinite conducts itself as a part, in as much as only a part of it is ever actual.

Explanations (Book 3, Lesson 12)

Infinity in numbers is opposite to that of magnitudes. For the unit is the principle of number, and divisions of numbers cannot go below the unit [since fractions and negative numbers are still computed in terms of a unit], but addition to number can go on without end. Magnitude, however, is always of a finite size, yet its division can go on infinitely [quantitatively, but physically there is a limit, just as there a physical limit to the size of anything].

Infinitude is not found according to the same respect in motion, magnitude and time. Rather, the infinitude of time derives from that of motion, of which it is a measure, and the infinitude of motion derives from that of magnitude, over which motion takes place, as will be explained in Chapter 7.

The infinite is a principle resembling matter, but not in so far as matter lies under a form, but in as much as matter has privation–for the infinite implies the lack of perfection and term. That is why the Philosopher adds that the notion of the infinite consists in privation. The *per se* subject of the privation which constitutes the nature of the infinite is the sensible continuum. This is clear from the fact that the infinite found in numbers is caused from the infinite division of magnitude; and similarly, the infinite in time and motion are caused by magnitude. Hence the first subject of the infinite is the continuum. And since really existing magnitude is not separated from sensible things, it follows that the subject of the infinite is sensible.

Answer to arguments for the existence of an actual infinite (Book 3, Lesson 13)

Here Aristotle answers five arguments advanced for the existence of something actually infinite:

1. If the world has always existed (as is logically possible), then there must be an infinite series of generations. – Such infinitude does not exist in act, but only in potency; each generation exists in act only successively.
2. Every body must be defined by its border with another body, and so on to infinity. – It is one thing to be "touched" and another to be "terminated. All that is required is that a body be terminated by its own surface. It is incidental to the finite that it be touching something else. Thus the outermost bodies of the universe need not be in contact with something further.
3. Space can be imagined as infinite. – We cannot transfer imagination to reality.
4. Time and motion are infinite. – They are not infinite in act, but only the present moment is actual.
5. Magnitude is infinitely divisible. – That points to a potential, not an actual infinite.

CHAPTER 7
PLACE, SPACE, VOID

After treating what pertains intrinsically to motion, the Philosopher now turns to what is extrinsically connected with mobile things. The first is place, which is the measure of mobile things–connected with place is concept of space or void–and then time, which is the measure of motion itself.

PLACE (Book 4, Lesson 1)

Why consider it?

The most basic and obvious of the forms of motion is local motion. This kind of motion cannot be understood without understanding place. Besides there have been some misunderstandings and controversies about the notion of place, which should be settled.

Reasons supporting the existence of place

1. The fact of place is clear from the fact of local motion. For just as the existence of matter came to be known from change according to form, so the existence of place is known from change according to place. Thus, when water is poured out of a vessel, air re-enters. Since, therefore, another body sometimes occupies the same place, it is clear that place is something different form the things that are in place and which are moved according to place. Consequently, place is something: it is a sort of receptacle distinct from any of the things located in it, and it is the term "from which" and "to which" of local motion.
2. The existence of place is also evidenced by the fact of "proper place", i.e. that heavy bodies are carried down and light ones upward; everything gravitates to its own place by a desire of self-preservation. This, however, does not prove that place has the power to attract, except in the sense in which the end is said to attract. Gravitation is also the basis for the concepts of "up" and "down". Other directions, such as "right" and "left", "before" and behind, are based on the position men or animals may be facing. If we were to speak purely mathematically and abstract from gravitation or the position of animals, there would be no basis for saying anything is in a certain direction.
3. Even those who assert that the void or space exists must admit that place exists, since the void is nothing more than a place devoid of any body. Likewise the poet Hesiod speculated that the first thing made was chaos, then the earth as a receptacle for bodies. He thought that place can exist without other bodies, but other bodies cannot exist without place.

7.1.3 Reasons challenging the existence of place (Book 4, Lesson 2)

1. If place is anything it must be a body, since place has three dimensions. But if a body is in a place, then two bodies must be together, which is impossible.
2. The surface of a body should be distinct from the surface of the place which is its receptacle. But two surfaces must be one surface, just like two points which touch; for two points joined together are just one point. Therefore the place of the body will not be different from the body itself.
3. If place is not a body, then it cannot have magnitude and cannot exist.
4. Everything that exists is somehow a cause in relation to other things. But place is not a cause: neither as *matter*, since nothing is made out of it, nor as *form*, since things of different species are in the same place, nor as the *final* cause, since places seem to be for the sake of the things in place rather than they for the sake of the places, nor as *efficient* cause, since place is the terminus of a motion. Therefore place seems to be nothing.
5. Zeno's reason: Whatever exists is in place; hence if place is anything it follows that it is itself in place, and that place in another place and so on *ad infinitum*.

6. Place is neither smaller nor larger than the thing in place. But when a thing in place grows, its place also should grow. However, this seems impossible, for place is an immobile something. Therefore place is not anything.

7.1.4 Reasons supporting that place is form or matter (Book 4, Lesson 3)

First, distinguish between **common** place and **proximate** place. It is true to say that I am in the world, but proximately I am on this chair in this room. Since place, then, seems to be the immediate boundary of a thing, it resembles form, since form limits matter to its own existence and magnitude to a determinate measure.

On the other hand, place seems to resemble matter. That is because it seems to be nothing other than the space enveloped by the boundaries of a container, which has length, breadth and depth. This space does not seem to be the same as any sensible body, because the space remains the same even when various bodies successively enter and leave it. Thus it follows that place is a set of dimensions separate from bodies. Therefore Plato argued that place is matter, since place is different from a body with definite dimensions and a numerical identity (since Plato made numbers and quantity the substance of things). Whether Plato held that place is exactly matter or else "the large and the small", it is clear that he defined place as some kind of receptacle.

If place is either form or matter, it will be difficult to define, since both form and matter are difficult notions and one cannot be know without the other.

Reasons why place should not be form or matter

1. Form and matter are not separate from the thing of which they are components, whereas place is distinct–in the place where air was, water now is. Likewise place is not an accident of a thing, since an accident cannot be separated from the thing. Nor can place be said to be matter, because matter does not contain but is contained by form.
2. Even if something never moves from its place, the very fact that we say it is **in** place shows that place is distinct from the thing and its form or matter.
3. Matter and form are part of the thing moved from one place to another. If matter or form were place, then place would move and be in place, which is nonsense.
4. In corruption the matter and the form are accidentally corrupted. But no explanation can be given of how place is corrupted; hence it cannot be said that matter or form are place.

Distinctions necessary for a definition of place (Book 4, Lesson 4)

Eight ways in which something is said to be **in** something:

1. The way a finger is said to be in the hand and in general any part is in its whole.
2. The way the whole is said to be in its parts. Since this way of speaking is not so common, we must understand that the whole is not something outside its parts, but exists in them.
3. The way "man" is in "animal", and any species in its genus.
4. The way a genus is in its species, such as "animal" in "man". That is because the genus is part of the definition of the species; so both the genus and the specific difference are parts of a whole.
5. The way health is in a balance of temperature, and any form is in matter or a subject, whether the form be accidental or substantial.
6. The way Nigeria is in the hands of the head of state, and anything moved in its mover. Thus we say "It is in me to do such and such", because it is in my power.
7. The way someone's heart is in what he desires and loves, and anything in its final cause.
8. The way something is in a vessel, and in general as a thing is in its place. The same could be said

of being in a certain time, for time is the measure of motion.

Of all these ways, the last is the most proper sense something is said to be **in** something. A thing in place is contained or included by its place and has rest and immobility therein. The nearest to this way is (1) the way a part is contained in an integral whole, as in a conjoined place. Then comes (4) the way a whole is contained in the definition of something, as "animal" in "man". Then (3) there is the way a species in a genus, which contains it an other species as well. Similarly to this is (5) the way form is contained in the potency of matter. Likewise (2) the whole resembles a form in being in its parts. And the way form is enclosed under the passive potency of matter, so (6) the effect is enclosed under the active potency of the agent. Finally (7) it is clear that the appetite rests in the good it desires and loves and is, indeed, fixed in it.

Other suppositions toward a definition of place (Book 4, Lesson 5)

So much is clear about place:

1. That place contains what is in place while remaining distinct from it.
2. Primary [= proximate] place is equal to, and neither greater nor less than the thing in place.
3. Everything in place has a place, although it can move from that place to another.
4. Every body has a gravitational attraction, which accounts for the directions of up and down; its density determines its natural level with reference to neighbouring bodies (e.g. water, oil, air).

A good definition of place should: 1) show what place is, 2) resolve conflicting arguments about place, 3) reveal the characteristics of place, since a definition is used as a middle term to demonstrate its proper accidents, 4) point out the reason why conflicting things were said about it. Such a procedure is the best way of defining anything.

The question of place would never have arisen were there no motion from one place to another. This takes place directly in local motion, and indirectly in growth, whereby a body acquires a larger place.

We must distinguish between **per se** and **accidental** motion. The latter occurs when, for example, we are sitting still in a moving car. The car is moving **per se**, and we are moving accidentally.

We must also distinguish between **primary** place, which is our immediate surroundings, and **common** place which is the larger area where we happen to be (e.g. town, country, continent).

Whenever the container is not separate from the thing contained but is continuous with it, the thing contained cannot be said to be in it as in a place, but as a part in a whole, for example my hand in my body, and it changes place along with the body. But if the container is separate and contiguous to the thing contained it is equal to it in dimension.

The definition of place (Book 4, Lesson 6)

First of all, place cannot be form, since it is extrinsic to what it contains.

Secondly, place is not the same as space, although it might seem to be, since space is thought of as absolute dimensions that do not change, whatever bodies happen to fill it. There cannot be any spatial dimensions apart from bodies and other environing or containing bodies, because if space were something with its own dimensions independent of bodies, then there would be two sets of dimensions that interpenetrate.

Thirdly, place is not matter, although place receives the different things it contains in a way resembling the way matter receives different forms. Yet matter becomes one thing with the form it receives, whereas place remains distinct from what is in it.

Therefore, place must be **the boundary of the containing body**, while the contained body is what is apt to be moved in respect to place.

Place is also in some way **immobile**. That is how a place differs from a **vessel**, because a vessel can be moved, but a place cannot. If I am riding in a car, I am not **per se** in motion, but the car is. I am at rest **per se**, but **per accidens** I am in motion. Therefore I am not staying in the same place. My place is determined not by the vessel which immediately contains me, but by reference to the place that contains the vessel. Thus a boat could be **per se** in motion going upstream on water that is **per se** in motion going downstream (a vessel in a vessel), both at equal speeds so that the boat remains in one place, with reference to the shore of the river. Likewise, the wind blowing on my face is not place, but only in so far as it is in position to the immobile surface I am standing on.

What gives stability to place? Natural place and rest is determined by gravitational force. Abstracting from gravitation, it would make just as much sense to say that a car is moving down the express way as to say that the express way (and surrounding world) is in motion and the car is standing still. On this planet gravitation determines whether we are going to the U.S. or the U.S. is coming to us.

Yet it is true [as Aristotle and Thomas Aquinas did not know] that the earth itself is a vessel carrying us around the sun, and the sun is carrying all its planets somewhere else, so that we cannot determine any fixed point of immobility in the universe–although, apart from gravitation, it would make equal sense to say that the earth revolves around the sun or the sun around the earth. Yet it is sufficient for distinguishing what is in motion from what is at rest to determine **relatively immobile** reference points determined by natural gravity.

Thus Aristotle concludes that *place* is **the immobile surface of that which primarily contains a body**. The word "primarily" designates proper place (the nearest immobile surface, if in a vessel) and exclude common place.

Explanations (Book 4, Lesson 7)

The universe as a whole is not in a place, since there is no outer containing body. Because Aristotle imagined the heavens to be concentric spheres around the earth, he inquires how a sphere moves. We could ask the same question about a ball spinning on a table. The ball is not changing place, and in this sense it is not in motion, but it is in motion by reason of its parts.

[Book 4, Lesson 8] As for some of the problems raised in Lesson 2, they are all solved by the definition of place as the surface of a containing body:

(6) that place should grow as a body grows–This would be so if place were a space co-extensive with the dimensions of the body, but if it is the boundary of the container, the growing body merely takes up more place.

(2) that two touching surfaces are one–This again is a confusion of place with "space" that has dimensions corresponding with the surface of the body. This, however, need not be said if we suppose that place is the boundary of the container.

(1) that place is a body, and so it and the located body are two bodies in the same place–This is a wrong supposition, since place is the surface of a containing body.

(5) that place is in a place *ad infinitum*–Rather, place is in a body not as in a place, but as a surface in a body.

7.1.10 Gravity

Bodies naturally gravitate to other bodies of greater density. We see it in drops of water or mercury coalescing on a table. We see all things about us gravitating to the earth. We observe through tides how the waters of the oceans gravitate towards the moon.

Aristotle and Thomas Aquinas were wrong in thinking that the more noble things (like fire) go up and earth goes down, and in their idea that the sun, moon and other heavenly bodies were incorruptible. Nevertheless they were fundamentally right in seeing gravity as a spontaneous inclination of bodies to be together for the purpose of survival. This idea, however, is inconsistent with another of their erroneous positions, namely, that the sphere of the stars is the first place and containing body of the rest of the lower universe. This is wrong, because we do not look up for a focus of natural place, but down to the earth, or to any other centre of gravity in the universe.

THE VOID

Arguments for its existence (Book 4, Lesson 9)

Change of place would be impossible if there were no void. That is because something cannot be moved into what is full, because a place filled with one body cannot receive another. Otherwise there would be two bodies in the same place. But there is motion. Therefore, there is a void.

Moreover, bodies that can be compressed or condensed seem to do so because the parts are pressed into empty spaces, like foam. Likewise, a body cannot absorb food and grow unless there is empty space into which the food can be taken. Besides, you can pour as much water into a bowl of gari as you can into an empty bowl; that shows that there are empty spaces in the gari.

The Pythagoreans not only posited an infinite void outside the universe, but also attributed the distinction of things in the universe to a void; according to them, numbers are the natures of things, and are distinct from one another by a void. This is using "void" in a quasi-equivocal manner.

The meaning of void & refutation of arguments for its existence (Book 4, Lesson 10)

According to common opinion, the void seems to signify nothing more than a place in which there is nothing. It is thought to be necessary to allow for the possibility of motion.

Yet besides local motion there is also alteration, which would not require a void.

Even local motion does not require a void if we suppose that bodies can contract so as to give way; this is especially evident when things pass through water or air.

Also, compression does not necessarily presuppose a void, but a porous material containing air, as in the case of gari, where the water poured in replaces the air.

Likewise food taken into a body does not require a void in the body, but it is altered and is converted into the substance of the body; this is not just a case of filling the stomach, but of the whole body growing.

Arguments from motion against a separated void (Book 4, Lesson 11)

1. The void is not a cause of motion, because bodies do not move because they are sucked into a vacuum, but because they naturally gravitate to their natural level.
2. The void, if taken as empty space, is something negative and can have no finality about it so as to be a destination of gravitation, unlike place.
3. Rather than being a requirement for motion, the void would actually make it impossible, since in a void there is nowhere to go; so a body would just rest.
4. Similarly, in a void we cannot speak of directions; therefore motion would be impossible, since it is always in some direction.

7.2.4 Arguments from the nature of a void against a separated void (Book 4, Lesson 13)

To say that a body moves in a void presupposes that the void is measurable, which means that it has

dimensions. In that case the dimensions of the moving body and the dimensions of the void would co-exist, and be the same as two bodies in one place.

Besides, there is no experimental evidence of a void; whatever might seem to be a void is just thin air.

Arguments against a void within bodies (Book 4, Lesson 14)

Some philosophers posited a void within bodies to allow for their contraction, so as to permit motion. That is because if there is no empty space in bodies, either there would be a total jam, with no body yielding to another, or anything moving in a straight direction would push everything in its path all the way to the edge of the universe, thus disturbing the heavens.

The same arguments that were used against a separated void apply to a void within bodies, but the phenomenon of expansion and contraction of bodies can be explained otherwise than by a void. Just as something can change from cold to hot, so its volume can alter because of the potency of the matter to different sizes, not by an addition of more matter. Things in a state of compression are heavier and harder than equal volumes of the same thing rarefied or expanded. Thus there is no need to posit a void in bodies to allow for motion.

CHAPTER 8
TIME

Arguments against its existence (Book 4, Lesson 15)

1. Time includes the past, present and future. But the past and the future do not exist. Therefore time does not exist.
2. Even present time does not exist, because time is divisible, whereas the "now" which exists, being indivisible, is not a part of time.

The question arises whether successive "nows" are distinct or the same. On the one hand it seems they are not distinct, since two parts of time cannot exist together unless one contains the other, as a year contains a month. But between two "nows" there are an infinity of "nows", so that one can never contain or even touch the other. Therefore, if time is continuous, the same "now" must perdure.

On the other hand, it seems that each "now" is distinct: No finite divisible thing can have just one boundary; thus a line must have two terminal points. But the "now" is a demarcation of time, and periods of time are determined by two points of time (= past or future "nows"). Therefore each "now" must be distinct. Likewise, if the same "now" perdured through all time, there would be no way of distinguishing the time of things that happened a thousand years ago from things that exist today.

How time is related to motion (Book 4, Lesson 16)

Time is not the same as motion, because motion exists in the particular things that are in motion, whereas time is everywhere and among all things. Besides, every motion is either slow or fast, but time is neither; rather it is the measure of what is fast or slow, since something is fast if it is moved a great distance in a short time.

On the other hand, time is not independent of motion. A sign of this is that we think little or no time has passed (or time has gone fast) if nothing is happening around us or we become so absorbed in something that we are unaware of what is happening around us.

Therefore time is not motion, but it does not exist without motion.

Definition of time (Book 4, Lesson 17)

Time is connected with motion. This is obvious by our perceiving the two together. Even if we in a silent dark room, we perceive the succession of our thoughts and imaginings, and by this are aware that time is elapsing.

The latter case would make it appear that time depends on the motion of the mind. In that case time will not be a thing of nature but a rational being. On the other hand, if time follows upon any and every motion, then there are as many times as there are motions, which is absurd.

The problem of multiple times is solved if we measure the multiple motions of this world by reference to regular cosmic motions, such as the daily revolution of the earth on its axis, the annual orbital movement of the earth around the sun, and the 28 day orbital movement of the moon around the earth. These are the constants of our world of experience, and it is by these motions that time is calculated.

If time is calculated according to such a basic local motion, and this motion is the continuous passage of the earth over a continuous orbit or position in reference to the sun, then time must be continuous. Because positions can be demarcated in the path of these motions, the motions themselves can be demarcated by points which are before or after each other. Because there is a priority and posteriority of motion, there is a priority and posteriority of time.

The priority and posteriority of motion are the same as motion as to subject, but are different formalities. *Time*, precisely, is **the number of motion**. That is because time is a counting of the different "befores" and "afters" of a motion. We could re-phrase our definition to say that *time* is **the numbering of motion according to before and after**. The "before" and "after" are not those of time, so that the definition would be circular, but the "before" and "after" of motion as it crosses different points of place.

As a number, time is not an abstract number, such as used in pure mathematics, but a concrete quantity that we can call a "numbered number", as when we say ten men or 100 horses. *Time* is the **number of before and after in motion**. Although number is discrete quantity, time is a continuous quantity on account of the thing counted, just as ten measures of cloth is a continuous quantity, even though ten is a discrete quantity.

The meaning of "now" (Book 4, Lesson 18 & 21)

Just as the parts of motion are always other and other, so also the parts of time. But what always exists throughout the whole of time is the same, namely, the "now" which, as to its nature is always the same, although in conception it varies according as it is prior and subsequent. Thus the "now" measures time not in as much as it is always the same thing, but in as much as in conception it is other and other, i.e. "before" and "after".

[Other words for "now" are: a "point in time", an "instant", a "moment", but the latter two are more often understood as infinitesimal segments of time.]

In so far as the "now" constantly changes with the succession of time and of motion, in that sense it is other and not always the same, but in so far as the "now" is a certain being, abstracted from "before" and "after", in that sense it is always of the same nature. "Now" is comparable to a moving car along a road; in its nature it is always the same, yet different when considered located at different positions along its path. Just as the mobile object is more known to us than motion, and motion is known through the mobile object, so time is known through the "now".

It is plain that if there is no time there will be no "now", and if there is no "now" there will be no time. Time is the number of local motion, but a single "now" is not the number of motion (since it is indivisible), but a principle of motion, just as "one" is the principle of number.

Just as the unity of the mobile (e.g. the car on the road) gives unity to the movement (since a change of vehicles would mean different movements), so time derives its unity from the moving "now". And like the moving point of a line as it is drawn, the on-going "now" both gives unity to time and distinguishes its parts. Points are only potential in a line and are actualized only when demarcated as the end of one segment and the beginning of another, as at an angle, which is one point serving two lines. Angular motion (like a bouncing ball), however, is multiple, with the two motions connected at two contiguous points.

The "now" of time is continuous like the point of a line, being at the same time a potential end of the past and beginning of the future. Only when we designate one "now" as the end of one period of time and the beginning of another is it an actualized point. [Compare the separate frames of a video film with the continuity of actual motion.] The distinction of the "now" is a work of the human mind taking it as a boundary; in reality there is no break into contiguous "nows", but it is continuous.

Thus the "now" is not a part of time, but a boundary of time; in that way it is a number, and is applicable to all things that are moved in time.

Besides its meaning as a point in time, "now" is commonly used for a period of time that includes the present, as we say "He has now come" because he has come today.

Similarly, we say something happened "then", meaning either at a precise moment in the past or at a

more or less broad period of time including that moment.

The words "presently" or "just now" mean "now" in the broad sense of the present time, while "long ago" refers to a period of time in the distant past. Something occurs "suddenly" when the time in which it takes place is imperceptibly small.

"Now" in its strict sense has the double function of being an end of the past and a beginning of the future. Thus, of its nature, time does not necessarily have a beginning or an end. Only were the whole universe and its motion to have a beginning would the first "now" serve only as a beginning and not as an end. And were the whole universe and its motion to have an end, then the last "now" would serve only as an end and not as a beginning.

Explanations about time (Book 4, Lesson 19)

We have seen that *time* is **the number of motion according to before and after**. It is a type of continuum; although it does not have continuity in so far as it is a number, it does by reason of that of which it is the number: for it is the number of a continuum, namely, of motion. For time is not a number absolutely but a number of something numbered.

Does time have a minimum? As a number, the minimum is one: a year, day or second etc., but as a continuum, any given time can be divided into smaller parts, just as a magnitude.

Why is time not said to be slow or fast, but is said to be much or little, and short or long? In so far as time is a continuum it is said to be long or short; in so far as it is a number it is said to be much or little. But it cannot be called fast or slow, because that is said of something that can be counted in a short or long time, whereas time is the number of a constant motion.

In what ways is time the same and different? Time is the same everywhere, but is different by reason of before and after in the basic motion of which it is the number; just as different segments of motion are different, so different segments of time.

How is time everywhere, when motion is not everywhere? The answer is that time accompanies motion, whether motion be actual or potential. For things that are capable of motion, and are not actually being moved, are at rest. But time measures not only motion but rest as well.

How can time be repeated? Since the same motion may be repeated specifically, but not numerically, so time can be duplicated in the same day. Thus each year we have a rainy season, specifically the same but numerically different.

Does time measure motion or motion time? Each is defined in terms of the other. The basic continuum is that of a magnitude (e.g. a road); motion imitates this in quantity, continuity and divisibility, and likewise time imitates motion. Fundamentally, time is the number and measure of motion, but it is not always the most known to us. Sometimes we say a certain town is two hours away, not knowing the exact distance. Other times we say that it is 60 kilometres, not knowing the time it takes to get there.

How things are or are not in time (Book 4, Lesson 20)

Motion is measured by time both in its duration (so many hours, days) and in its being, which is essentially continuous and numerable. Other things, like a stone or a man, are measured by time in their duration (i.e. in so far as they have motion), but not in their being, which merely co-exists with time.

Anything that exists in time tends to waste away with age. Even though it could be argued that some things get better with time, nonetheless one does not necessarily learn with time but one does forget with time. Time is *per se* corruptive, and *per accidens* generative, whereas generation and being is attributed *per se* to the agent and generator. The latter are not required for corruption, but simply old age.

Thus whatever is contained in time is subject to decay and corruption. But whatever is outside time exists forever. Aristotle and Thomas wrongly thought this applies to the heavenly bodies which have only local motion but are subject to no other change. But if heavenly bodies, like the sun, moon and stars, are corruptible like everything else, then only spiritual beings are outside of time and exist forever. Besides, universal truths, such as mathematical axioms, are not subject to time and are forever true, but that is because they are abstracted from the real sensible existence of things.

Problems regarding the existence and unity of time (Book 4, Lesson 23)

1. Can there be time without the soul? An argument for the negative is that without anyone to count nothing is countable, and there is no number. On the other hand, motion is a reality independent of the soul, and so is its "before" and "after", which is numerable. Consequently, just as there can be things perceptible to sense even though no sense exists, and intelligible things even though no intelligence exists, so there can exist both countable things and number, even though no counter exists. It is true that if it is impossible for a counter to exist, then nothing countable could exist, but it does not follow that if there is no one counting that there is nothing countable.

Motion, however, does not have a fixed existence in reality, nor is any par of motion actually found in things but a certain indivisible of motion which divides motion; indeed, the totality of motion comes to be on account of the mind considering and comparing a previous state of the mobile to a subsequent state.

According to this, then, time also has no existence outside the soul except according to its indivisible, while the totality of time is had by an ordering process of the mind enumerating what is prior and subsequent in motion. Therefore, apart from the soul time is "a sort of being", i.e. an imperfect being, just as motion exists imperfectly without a soul knowing it.

2. Of which motion is time the number? Since every motion has a before and an after, it would seem that time is the number of each and every motion. But in this case two simultaneous motions would each have their own time (or calendar) and two equal measures of time would exist simultaneously. The only way to compare them is by some regular constant motion, such as the spinning of the earth, which gives us day and night, and the revolution of the earth around the sun, which gives us a year.

CHAPTER 9
THE KINDS OF MOTION & THEIR CONTRARIETY

***Per se* & *per accidens* motion** (Book 5, Lesson 1)

On the side of the **mobile**, *per accidens* motion is that ascribed to something wider than the proper subject of the motion. For example, (1) "A musician is walking": The person is the proper subject, who happens to be a musician (an accidental). Or (2) "I have been healed", when my injured finger (a part) is healed. (3) *Per se* motion is that ascribed to a subject properly and as a whole.

On the side of the **mover**, the same distinctions can be made, such as: (1) "The musician is building" (accidental); (2) "I am pounding" (because of a part); (3) "The healer heals" *per se*.

As for the **terminals** of motion, we must first remark that for motion five things are required: (1) a mover or efficient cause, (2) the mobile or subject of the motion, (3) a time in which the motion occurs, (4) a starting point/ terminal of the motion, and (5) the end point/ terminal of the motion, since every motion is from something into something.

Whatever is being moved *per se*, i.e. the mobile, is distinct from both terminals of motion: e.g. the food (not the cold) is being heated; while in motion it is neither cold nor hot, but somewhere in between, tending towards heat. But *per accidens* the cold (the privative starting point) becomes hot.

The **final terminal** *(terminus ad quem)* **specifies a motion**; thus any change is named after its destination; e.g. heating is an alteration terminating in heat.

The species of *per se* change (Book 5, Lesson 2)

With regard to the starting and ending terminals of change, any change is from a non-subject to a subject, or from a subject to a non-subject, or from a subject to subject. Change from a non-subject to a subject takes place between contradictories and is called *generation*. The subject of this change is not an actual being, but a merely potential one, namely, prime matter; so in the case of a substance being generated, it is said that something comes to be in an unqualified sense. The term "generation" applies in a wide sense to change between accidental contradictories, such as from non-white to white, where the subject remains the same.

Change from subject to non-subject is also between contradictory terminals and is called *corruption*. Similarly in only a broad sense does "corruption" apply to change between accidental contradictories, such as from white to non-white.

Generation is not motion, because what does not exist cannot be moved, and if it exists it is already generated. Of the types of non-being, a logical negation in a judgement of the mind indicates the falsity of a statement, and is not subject to motion.

In another way non-being does not exclude unqualified actual existence, but only actually being such-and-such, for example when non-white is called non-being and non-good. Such non-being is subject to motion *per accidens*, in as much as it is attached to an actually existing thing subject to motion, as when a man is said to be non-white.

Thirdly, what is in potency is called non-being in so far as being in potency is the opposite of unqualified being in act; in this sense no motion is possible. Although something comes to be *per accidens* from non-being and *per se* from a being in potency, yet it is true to say of what is absolutely coming to be that, strictly speaking, it is non-being and is in no place. Such a thing cannot be moved; hence generation is neither motion nor rest.

For the same reason corruption is not motion. Both generation and corruption are instantaneous, whereas motion is continuous.

Change from subject to subject, however, is motion. By two subjects is meant two affirmative contraries or intermediates (e.g. white, grey, black).

Categories that do not admit of motion (Book 5, Lesson 3)

Since motion is defined by its final terminal, and these terminals are distinguished according to the genera of the predicaments or categories, the kinds of motion must fall within these ten categories. Only three of them admit of motion: **quantity, quality** and **location**. Because it is an imperfect act, motion does not belong by full right to these categories, but it is placed in them by reduction.

There is no motion in the category of **substance**, because motion is between contraries, but nothing is contrary to substance; there is only the contradictory "non-substance" (or "man" and "non-man"). If substances are contrary to one another (like fire and water), that is not as substance, but with respect to active and passive qualities. Even though the definitions of substances include specific differences which are based on a contrariety of excellence and defect, the resultant species are discrete, like different numbers, and there is no continuity between them so as to allow for motion or gradual passage of an individual of from one species into another.

Nor is there motion in the category of **when**, which expresses existence in time, which is the measure of motion. **Position** is the order of parts, which is a relation resulting from their motion. **Habit** also is a relationship between a body and what is adjacent to it.

There is no motion in **relation**, because a relationship can change without any movement in the subject, as when someone grows to be equal with you in height. Also there are some relations which are not real but only of the mind in one or both terms. For instance, the sameness of a thing to itself is a relation of reason only, while "to be known" is a real relation in the knowing human intellect, but not in the thing known.

The relationship of motion to the agent and the mobile is called **action** and **passion**. Although used often to include motion, there is no motion in these two as distinct categories.

Categories which do admit of motion (Book 5, Lesson 4)

Only in **sensible qualities, quantity and location** is there to be found continuity and contrary extremes of possible motion. The contrary extremes of sensible qualities are evident. In the case of quantity, there is a minimum quantity at which the motion of growing begins, and a maximum at which it is terminated. Likewise in place there are two terms which are most distant in respect to any particular motion.

Motion according to sensible qualities is called **alteration**; motion according to quantity is called **growth** or **decrease**, while motion with regard to location in place is called **locomotion**, or simply motion.

In order for there to be alteration, it makes no difference whether the change is unqualifiedly from contrary to contrary, or from more to less or less to more. In the former case the terminals of the alteration are two actual contraries, like white and black, whereas in the latter case the subject has a in greater or lesser degree one or another of the contraries.

The term **immobile** has various meanings: (1) what is absolutely incapable of being moved, as God, (2) what is moved with difficulty, either because it is difficult to start moving (like a big rock) or once it gets going it moves slowly (like a lame person), (3) what is capable of being easily moved, but is not in motion; this is called **rest**, which is the privation of motion in what is capable of motion.

Alteration is not found in other species of quality (Book 7, Lesson 7)

In Book 7 Aristotle branches into a discussion that is better been raised in discussing the species of motion. He had shown that alteration is possible with sensible qualities (the third species of quality). Here he shows that the fourth species of quality (form and figure) and the first (habit and disposition) are not matter for alteration. Although these qualities can be newly acquired, they are not acquired directly, but subsequent to alterations of the primary (sensible) qualities. Thus a different shape arises from compression (density) or local motion of parts, and a change in health (a disposition) results from temperature change or corruption of cells by sensible alteration.

It can also be said that there is no alteration in the second species of quality (natural potency and impotency), because these are not received or lost without a change in the nature, which takes place through alteration.

An indication that there is no alteration in form and figure (or shape) is that the shape of a thing is the closest accident to the substance and the most representative of it, since we distinguish things by their shapes. Therefore, just as we do not say "Man is earth" but "Man is **of** earth", so we do not say "This triangle is wood", but "This triangle is wooden". Thus the shape is a perfection like the form of a thing, which is a part, not the whole, and cannot be predicated of the whole. On the contrary, sensible qualities can be convertibly predicated of the whole, e.g. "This wood is wet" and "This wet thing is wood".

The reason that there is no alteration in bodily habits and dispositions is that these consist of harmony or due proportion of the composing elements of the body. This is true of health, beauty and agility. All such harmonies are of their very nature relations, and in relation there is no motion or generation or alteration, but relations begin to exist as a consequence of certain motions or changes.

Alteration is not found in habits of the soul (Book 7, Lesson 6)

After showing that alteration does not occur in the first species of quality in respect of dispositions of the body, the Philosopher shows the same about the habits of the soul. First he says that there is no primary and *per se* alteration in changes that affect virtues and vices in the sensitive part of the soul. That is because virtue is a perfection and a form, like shape, discussed above. Nevertheless they come about as a result of alteration of the sense appetite, which requires moderation in what it delights or is sad about.

Similarly alteration is not found in the intellectual part of the soul. That is because knowledge is a relationship, since truth is the correspondence of the mind to reality; and there is no motion in relationship. Nevertheless knowledge comes about as a result of alteration, in two ways: First, our knowledge comes through the senses; thus the senses must be altered for an image to be presented to the intellect. Secondly, unregulated passions can be an obstacle to knowledge; thus their regulation, which involves alteration, is a *per accidens* requirement for knowledge.

The definitions of *in contact, consecutive, continuous* (Book 5, Lesson 5)

After dividing change and motion into its species, the Philosopher now begins to discuss the senses in which motion is said to be one and the senses in which motions are said to be contrary. Therefore he now establishes some preliminary notions that need to be understood.

1. Things are **together** which are in one first place, as opposed to a common place, such as "in Africa". Things which are not in the same first place are said to be **separate** or **apart**. Things are **in contact** whose terminals are together. The terminals of bodies are surfaces, those of surfaces are lines, and those of lines points. So things which touch at one or more points are in contact.

2. The **between** is what a changing thing arrives at before it reaches the ultimate terminus of the motion. There can be a number of **between**s to be traversed from one extreme to another, but there must at least be two extremes and something between. For motion between two extremes to be one

and continuous, there must be no interruption in time, because even the slightest interruption of the motion in time prevents the motion from being continuous. There is something between contraries, but not between contradictories.

Nevertheless on the side of the magnitude over which the motion passes there can be variations that do not break the continuity of the motion: e.g. bumps and go-slow; so long as there is no complete stop, the motion is continuous.

3. For something to be **consecutive** it must come after the first and be in a certain order: either according to position, as things that are in order in place, or according to species, as 2 comes after 1, or in order of virtue, dignity, knowledge etc. For something to be consecutive it is also required that there be nothing intervening between it and what it is consecutive to, as for one number to be consecutive to another or one house to another. But something of another genus may intervene, e.g. an animal between two houses.

The **contiguous** is a species of the consecutive. Something consecutive is also contiguous when it is in contact, with nothing at all between of the same or any other genus. When the end points of two segments are one they are continuous; when they are two actual points, the segments are contiguous.

Thus consecutiveness is the broadest term; contiguity is narrower and presupposes consecutiveness; continuity is still narrower and presupposes contiguity. Another observation is that points differ from units in that points are present in things that can have mutual contact, but units can only be consecutive; thus there is nothing intermediate between 2 and 1.

Generic, specific and numeric unity of motion (Book 5, Lesson 6)

Motions are said to be **generically** one which are assigned to one and the same category. Thus every local motion is one generic motion, because each is in the category of **where**, and differs generically from alteration, which is in the category of **quality**.

Motions are **specifically** one which take place in a species incapable of subdivision. For some species can be sub-divided into other species: Colour, which is itself a species of quality, has sub-species making different species of motion, such as whitening and blackening; but all cases of whitening are specifically the same.

Some motions may be one on the level of intermediate species, but different in sub-species. Thus knowledge is a species of quality, and so all learning, which is a movement towards knowledge, is in this way one, but learning grammar is absolutely different in species from learning geometry.

If the goals of a movement are identical and the paths specifically the same (i.e. in a straight or determined curved line), then the motions are specifically the same; and much more so if the goals and the path are numerically the same, repeated motions will be specifically the same.

A motion is **numerically** one and the same if (1) the mobile subject is numerically the same, (2) if it is in a single species of motion, and (3) if the time in which the motion takes place is continuous without any break. To recover twice from the same disease is to recover numerically the same health, since the original health was never totally destroyed, but the recoveries are numerically different because they are not continuous, but in separate times.

More on numerical unity of motion (Book 5, Lesson 7)

Motion is numerically one not the way an indivisible is one, but the way in which a continuum is one. For motion to be continuous it must have extremities of the same species; thus one cannot move from whiteness to knowledge. Nevertheless, separate motions of different species or genera can be going on in the same subject at the same or time or consecutively.

If the same subject is moved according to the same species in one continuous time, the motion is numerically one, but it is more perfectly one if it is regular or uniform, both as to speed and as to path, i.e. uniformly straight or circular; a motion is regular if any part of the motion (a segment of straight or curved line) taken randomly should fit over any other part.

Contrariety of motions (Book 5, Lesson 8)

There are five possible ways in which contrariety of motions might be considered:

1. By approaching or departing from the same terminus: e.g. a motion to health or from health.
2. By a contrariety of the terminals from which the motion begins: e.g. a motion from health and a motion from sickness.
3. By a contrariety of the ends at which they terminate: e.g. a motion to health and a motion to sickness.
4. By contrariety of the start of one and the end of the other: e.g. one from health and one to sickness.
5. By contrariety on the part of both terminals of each motion: e.g. a motion from health to sickness and a motion from sickness to health.

Of these, motions of the fourth type are not contrary, since a motion from health is the same as a motion to sickness.

Likewise motions of the second type are not contrary, because motions to the same goal are not contrary, regardless the starting point; thus two motions that start from contraries could terminate at the same intermediate point. Also, contrariety of goals is a greater cause of contrariety of motions than contrariety of starting points, since the goal specifies a motion.

The third and the fifth ways are basically the same, and only these are truly contrary. Contrariety is based on the specific nature of motion, which is from one positive contrary to another. Therefore contrary motions are those which have contrary terminals; for example, one from health to sickness is contrary to one form sickness to health; the same for an upward and a downward motion, or a motion to the right and one to the left.

If contrariety is taken as merely approaching or departing from the same goal (the first possibility above) there can be contrary **change** which is not motion; e.g. generation and corruption are contrary because they are changes to being and non-being respectively.

As for goals that are intermediate between contraries, the intermediate can serve as a contrary, no matter in which direction the change may be. For example, grey in a motion from grey to white takes the place of black as a starting point, but in a motion from white to grey it takes the place of black as a goal. For the middle is in a sense opposed to either of the extremes.

Contrariety between rest and motion (Book 5, Lesson 9)

Since not only motion can be contrary to motion, but also rest can be contrary to motion, we have to see how the latter is possible. Strictly speaking, only motion is perfectly contrary to motion. But, since rest is a privation of motion, it is somehow a contrary to motion.

Not any state of rest is indiscriminately opposed to just any state of motion, but a definite type of rest to a definite type of motion. For example, rest in place is opposed to motion in regard to place. But we must ask whether that rest which is whiteness is opposed to whitening or to blackening.

Since motion is between two positive terminals, the motion from whiteness to blackness is rest in whiteness, while the contrary of a motion from black to white is rest in black. That is because rest in the goal of motion is the consummation and perfection of that motion; since motion is the cause of that rest it cannot be its opposite.

Two states of rest can also be contrary. These are those which correspond to contrary motions: e.g. rest in health is opposite to rest in sickness.

In the case of changes that do not involve contrary terminals, such as generation and corruption, opposition is based on approach and departure from the same terminal. Neither of these changes is motion and therefore neither have an opposing state of rest. Rather the opposite of such change is non-change; that is, non-change in a non-being (= potential being) is opposed to change towards being, while non-change in a being is opposed to change towards non-being (potential being); this opposition corresponds to that between contrary motions. The opposition corresponding to that between rest and rest is non-change towards being (in a potential being) as opposed to non-change toward non-being in an actual being.

Opposition between natural and unnatural motion (Book 5, Lesson 10)

How are motions according to nature or contrary to nature, and how does this difference set up a contrariety of motions? Motion according to gravity is natural, coming from an intrinsic principle, while that contrary to it is violent, because it comes from an extrinsic principle. The same can be said for growth to maturity and qualitative change, such as motion to health (although the generic nature of contrary elements in an organism are intrinsic principles of corruption).

Thus motions have a contrariety not only because they have opposite starting and ending points, such as up and down, but also a contrariety on the basis of where they tend to go by natural principles; thus gravity brings bodies down. The same multiple opposition can be said to exist between motion and rest and between rest and rest. Thus for a heavy body to rest on the ground is contrary to its being lifted up in the air, and is also contrary to its being suspended in the air. Similarly, avarice is opposed to prodigality on the basis of contrariety of habit, since the avaricious person gives nothing while the prodigal person gives everything. The two, however are both opposed to generosity as vice to virtue, since avariciousness and prodigality are contrary to nature, while the virtue of generosity is according to nature.

CHAPTER 10
THE DIVISIBILITY OF MOTION

No continuum is composed of indivisibles (Book 6, Lesson 1)

If continuous things are those whose extremities are one (e.g. a line), it is impossible for it to be composed of indivisibles (e.g. points in a line). If something is composed of parts, the extremities must either be one (**continuous**) or they must be together (**contiguous**). But the extremities of points cannot be one or together, because an extremity is spoken of in relation to a part, whereas an indivisible is not related to any part. Besides, if a continuum is composed solely of points, they cannot touch, since everything that touches another does so by a part touching the other. But since an indivisible has no parts, a whole point must touch a whole point without distinction as to place or position; such a conjunction cannot result in a continuum.

Nor can a continuum be composed of **consecutive** indivisibles. This is because consecutive things, by definition, have nothing of the same kind intervening. But between any two points there is always a line, and if a line is composed of points only, then between any two points there is always another mediate point. The same is true for the "nows" of time; no time can be composed solely of "nows". Besides, a continuum is "that which is divisible *ad infinitum*", but if a continuous line is composed of indivisibles, then these indivisibles would have to be divisible, which is nonsense.

Thus between two points there must always be a line, and between two "nows" there must always be time. That is because, if two points exist, they must differ in position; otherwise they would not be two, but one. No other intermediate is possible except a line between two points and time between two "nows", because if the intermediate ever divisible into indivisibles the same problem would return as above–how a divisible can be composed solely of indivisibles. If the intermediate is always divisible into further divisibles, then it is a continuum.

No motion is composed of indivisibles (Book 6, Lesson 2)

Magnitude and motion are correlative, so that if magnitude is composed of indivisibles, so must motion, which traverses it. And if this is impossible for magnitude, then it is also impossible for motion.

To illustrate this, take a magnitude (or road) that consists of points A, B and C. When the mobile reaches B point it must either be in motion or have completed its motion. If it is still in motion, then B must be divisible; otherwise the motion would be complete at that point and the sum of the motion from A to C would not be divisible motions but discrete moments [like frames in a video].

Then, if motion consists of discrete moments, it would follow that something has completed a motion without having been in motion. Also it would follow that at each point on the route the mobile would be at rest, while it was supposed to be in motion. Also the segments of motion corresponding to each of the points on the route would also be rests, and thus the whole motion would be composed of non-motions.

No time is composed of indivisibles (Book 6, Lesson 3)

Time is divisible just as the magnitude being traversed in time. Thus a mobile going at an equal speed covers half the distance in half the time of its journey. Therefore the two are correlatively divisible into smaller and smaller segments.

The same can be seen from mobiles of different velocity: When the fastest reaches the finish line, the other is at some intermediate point; likewise the faster mobile reached that intermediate point in less time. This shows that the magnitude and the time are equally divisible. As we increase velocity, we divide time, since the journey is finished in shorter and shorter times. But if we decrease the velocity

and stop the mobile after the same length of time, we divide the magnitude, since less and less distance is traversed.

Although there are physical limits to division of a magnitude, just as there are physical limits to the size of a natural thing, so there are natural limits to velocity, but mathematically both magnitude and time are infinitely divisible, and the same magnitude is traversable in ever faster speeds.

No continuum is indivisible (Book 6, Lesson 4)

Because time corresponds to magnitude, if magnitude could be infinite, such as a line without beginning or end point, so would time be (since any finite time at a finite velocity will only traverse a finite magnitude). And if magnitude is infinitely divisible, so is time. The argument can validly be reversed: If time is infinite in length, so must magnitude be (because any motion, however slow will eventually traverse a finite magnitude); and if time is infinitely divisible, so must magnitude be.

From this we have another argument why no continuous magnitude or part thereof is indivisible. This can be shown inductively by positing two mobiles of different velocities. When the faster one crosses the first supposedly indivisible part, the slower one will have crossed only part way, proving that the supposedly indivisible segment is divisible.

The indivisibility of "now" and divisibility of the motion (Book 6, Lesson 5)

The term "now" is often used for a period, like "today", but "now" is precisely indivisible and present in every time. It is the limit between the past and the future, and as such must be one. The now terminating the past and beginning the future cannot be two contiguous "nows", because otherwise time would be composed of an aggregate of indivisible "nows", which is impossible, since it is continuous. Nor can there be an interval between the two "nows", because that would be a period of time or at least another "now"; in either case the "now" would be divisible. Were the "now" to be divisible it would have to include some of the past or the future; in that case some of the future would be in the past and some of the past in the future. Therefore the "now" which terminates the past and begins the future must be one "now".

Consequently, there can be no motion in a "now", since motion is continuous, while the "now is not; this can be proved (as above) by positing two mobiles going at different velocities; if there were motion in the "now", the faster would have traversed the same distance in less than a "now", making it divisible.

Likewise there can be no rest in a "now"; that is because rest is the privation of motion, and there is no privation where there is no aptitude to have the object of privation. So, if there can be no motion in the "now", there can be no rest either. Also, should the "now" be the termination of motion and the beginning of rest, then, were there to be rest in the "now", something would be both in motion and at rest in the same now. Rather, rest is understood as something continuous, like motion.

All motion occurs in time and must be intermediate between two extremes, with part of the mobile towards one extreme and part of it towards the other. This is obvious of the three species of motion, but, even though generation and corruption are substantial changes and instantaneous, they are preceded by alteration of a subject. Some alteration, like electricity in a wire, seems instantaneous, but precise measurements can show that it too takes place in time.

Two ways motions is divided (Book 6, Lesson 6)

Motion is divided according to the motion of the parts of the mobile, since both time and the mobile is continuous and divisible. Thus the entire motion belongs to the entire mobile, just as the parts of it belong to the parts of the mobile. Motion is also divided according to time, since there is less motion in less time.

In fact, there are five things related to motion which are similarly divided: (1) time, (2) motion, (3) the very act of being moved, (4) the mobile which is being moved, and (5) the species of motion, i.e. the place, quality or quantity. The divisibility of the mobile is the basis of the divisibility of all the others.

The beginning and end of motion are indivisibles (Book 6, Lesson 7)

It is first obvious that substantial change is the instantaneous moment when something ceases to be what it was and becomes something else. But the end of any motion is similarly and indivisible moment, when something can first be said to "have changed".

The beginning of a motion is likewise an indivisible moment. It is impossible to assign a first time when a thing began moving, because any time is divisible.

Every "being moved" is preceded by a "having been moved" and every "having been moved by a "being moved" (Book 6, Lesson 6)

Since motion is continuous and infinitely divisible, while anything is being moved, any past point of the motion can be designated where the mobile can be said to "have been moved", and in which there is no motion. This point marks a part of the motion which has been completed. Such a point is only potentially a term of motion, since the motion did not stop there.

Any such point that is selected as marking "the journey completed thus far" is preceded by another segment of the motion, or a "being moved"; otherwise it would be the beginning point of the motion.

These two statements can be proved, as above, by showing how two mobiles of different speeds mark segments of motion. They do not apply directly to generation and corruption, since these are not continuous motions but an instantaneous change. Nevertheless, generation and corruption are the term of a process of alteration, and the alteration, named after its term, is divisible: Thus "dying" is a motion that can be divided into stages.

Magnitude, motion, time and the mobile are all infinite or finite in the same way (Book 6, Lesson 9)

If magnitude (i.e. the path) is finite, time cannot be infinite, and if time is finite magnitude cannot be infinite; this can be shown by a comparative multiplying of the finite or dividing the infinite.

By similar arguments it can be shown that a mobile cannot be infinite if either the magnitude or the time is finite. The same thing can be said about motion.

The division of rest (Book 6, Lesson 10)

First, it is clear that "coming to rest" is part of motion, and this takes place in time. Just as we have seen that no part of motion can be said to be **first**, so no part of coming to rest can be said to be first.

Likewise, rest itself, being continuous in time, can have no first part, since each part is divisible. Something is at rest if throughout a definite period of time (from one "now" to another) it is one and same state, for example in one place. Therefore nothing can be at rest and at motion at the same time with respect to the same kind of motion.

Refutation of Zeno's denial of the possibility of motion (Book 6, Lesson 11)

The following are some of Zeno's reasons to show that local motion is impossible:

1. To traverse any space, a mobile must first go half way; since any space is infinitely divisible and the infinite cannot be traversed in finite time, nothing can be moved. The answer to this is that the infinite points in any distance are not actual but only potential.
2. Similarly, a faster mobile can never catch up with a slower mobile that started earlier, because

likewise it must first reach the point where the first mobile was. As it gains on the first mobile the points become nearer and nearer by infinite division, so that it never catches up. The answer to this is the same as above, since these points are not actual but only potential.

3. Time is made up of instants, and in every instant of time there is rest and not motion. The answer to this is that time is composed of only potential, not actual instants. Besides, just as there is no motion in an instant, so there is no rest.

Indivisibles are incapable of *per se* motion (Book 6, Lesson 12)

Democritus thought that indivisible atoms are *per se* mobile. But points exist only as the terminations of lines and move accidentally as the body in which they are found is moved. But granted that indivisible atoms could exist on their own, they could not be partly in one place and partly in another as extended mobiles are while in motion. Therefore they would have to cross the distance point by point and "now" by "now", and that is impossible. Therefore they would have to be permanently at rest.

No change is infinite (Book 6, Lesson 13)

Changes which are between contradictory terminals, which are affirmation or negation of something, as in the case of generation and corruption, are instantaneous and do not go on for any time, much less forever.

Changes that are between contrary terminals have a maximum and minimum term according to the nature of the subject and the species of change: thus every alteration has some limit. The same can be said for growth and decrease, because each nature has a size that befits it: there is one for a man and another for a horse. Therefore none of these changes can be infinite.

The same cannot be said of local motion, because not every local motion is between strict contraries, where contraries refer to things most distant. Gravitational motion has a definite term, that is the place where the falling body rests; so this is not infinite. But for motion to endure throughout infinite time in such a way that it remains one numerical motion can occur only in circular local motion; thus orbital motion can endure as one and continuous throughout infinite time, as will be seen later.

CHAPTER 11
THE CAUSE OF MOTION

The mover and the moved must be in contact in local motion (Book 7, Lesson 3)

When we say that the mover must be in contact with the moved, we are not talking about the final cause, which can be distant, but about the efficient cause. This can be seen in the three kinds of motion:

As for local motion, we have seen (in Lesson 1) how one thing is moved by another, where the mover is in contact with the moved. There are various ways a mover imparts local motion: by pushing, pulling, spinning, and carrying. Pulling can be reduced to pushing, since that is what the hook does to the part it is hooked onto. The difference between the rest is that pushing imparts a *per se* motion to the mobile so that it changes place. Spinning imparts a motion that is *per se*, but only by reason of the body's (potential) parts, which constantly change position while the body stays in the same place. Carrying imparts a *per accidens* motion, in that the mobile rests on the carrier which is in motion *per se*.

Aristotle mentions three cases of local motion where the moved does not seem to be in contact with the mover. These are gravitational motion, the motion imparted by a magnet, and the motion of a projectile after it has been thrown. We will explain and assess Aristotle's views on these questions later.

The mover and the moved must be in contact in alteration and growth (Book 7, Lesson 4)

For alteration it is obvious in most cases that the altering agent comes in contact with what it alters. But there are case of the agent operating through a medium, as the sun heating the earth. The contact of an altering agent and alteration is obvious in sensation, which takes place when the sense organ is altered. In this way the senses perceive heaviness and lightness, hardness and softness, dryness and wetness, density and rarity, sounds, brightness and colours, sweetness and bitterness etc. In all these cases the agent either touches the sense organ or acts on it through a medium, such as air or water.

In the case of growing, what is added to an organism by way of nourishment, must come in contact with the organism before it can be assimilated.

Opinions on the eternity of motion (Book 8, Lesson 1)

Democritus supposed that the first principles of things are bodies that are *per se* indivisible and always mobile and that the world came to be by the chance aggregation of these bodies–not only the world in which we exist, but an infinitude of other worlds in diverse parts of infinite void. Still he did not posit these worlds as fated to endure forever; rather, some came into existence as a result of atoms combining, and others passed out of existence as a result of the same atoms scattering. Therefore all the philosophers who agree with Democritus assert the eternity of motion.

On the other side, Anaxagoras held that there was a time in which nothing was in motion, when everything was mixed together and at rest for an infinite past, until Mind, which alone was unmixed, began to separate things one from another.

Empedocles also denied the eternity of continuous motion, but held that from eternity motion has alternated with rest in cycles, so that at certain periods all things are at rest (at least with respect to the general change of the world) and at others things are in motion. For him, Friendship and Discord, being respectively the principles of unity and multiplicity, are the causes of motion.

[In the ancient world, only Judaism held for creation in time, even though the letter of *Genesis* 1:1 could accommodate Anaxagoras' view.] Thomas comments:

> This method of proving the existence of a first principle is most efficacious and irresistible. for if

on the supposition that both motion and the world existed forever, it is necessary to posit one first principle, then, if the eternity thereof should be rejected, it is all the more necessary, for it is clear that every new thing requires a principles bringing it into being. Now the only reason why it could seem that no first principle would be necessary, would be if things were *ab aeterno*. But if the existence of a first principle follows even on that supposition, i.e. that the world existed *ab aeterno*, it is clear that the existence of a first principle is absolutely necessary.

An argument for the eternity of motion (Book 8, Lesson 2)

As principles of his argument, Aristotle recalls that motion is always in a mobile, and that a mover is also required for motion. If, then, it is held that motion has not always existed, it is necessary to say either (1) that mobiles and movers at one time came into existence–but that presupposes another change with movers and mobiles, since nothing comes from nothing, or (2) that they are eternal–then motion could never begin without some change in the mobiles or the movers disturbing the rest of all things. Even an intellectual mover, which is free to move or not move, can be supposed to act in the same way normally and *per se* (like a doctor acting to heal), but only *per accidens* do the contrary.

Similarly, motion is destined always to be. That is because from something never comes nothing; every change is into something else, matter being indestructible.

Thomas' Critique of the Arguments of Aristotle and Ibn-Rushd (*ibid.*)

Ibn-Rushd's arguments in support of an eternal past

From this argument of Aristotle, Ibn-Rushd took occasion to speak against what is held by faith about creation. For if coming-to-be is a kind of change and every change requires a subject, as Aristotle here proves, it is necessary that whatever comes to be does so from a subject; therefore, it is not possible for something to come to be from nothing.

He confirms this with another argument: When it is said that the black comes to be from the white, this is not to speak *per se*, in the sense that the white itself is converted into the black, but it is to speak *per accidens*, in the sense that upon the departure of the white, the black succeeds it. Now whatever is *per accidens* is reduced to what is *per se*. But that from which something comes to be *per se*, is the subject, which enters into the substance of what comes to be. Therefore, whatever is said to come to be from its opposite comes to be from it *per accidens*, but *per se* it comes to be from the subject. Accordingly, it is not possible for being to come to be from non-being absolutely.

In further support of his position Ibn-Rushd adduces the common opinion of the early philosophers that nothing comes from nothing.

He also gives two reasons from which he considers that the position arose that something should come to be from nothing. The first is that ordinary people do not consider as existing anything but what is comprehensible by sight; therefore, because they see something visible come to be which previously was not visible, they think that it is possible for something to come to be from nothing.

The second reason is that among the common people it could be thought to be a weakening of the power of the agent that it should need matter in order to act, which condition, however, does not derive from the impotency of the agent, but from the very nature of motion. Therefore, because the first agent does not have a power which is in any way deficient, they think that it should act without a subject.

But if one considers rightly, Ibn-Rushd was deceived by a cause similar to the cause by which he claimed we are deceived, namely, by considering particular things. For it is clear that a particular active power presupposes the matter which a more universal agent produces, just as an artisan uses the matter which nature makes. From the fact therefore, that every particular agent presupposes matter which it does not produce, one should not suppose that the first universal agent–which is active with respect to all

being–should presuppose something not caused by it.

Nor, moreover, is this in keeping with the intention of Aristotle who in *Metaphysics II* proves that the supremely true and the supreme being is the cause of being for all existents. Hence the being which prime matter has–i.e. a being in potency–is derived from the first principle of being which is in a supreme way a being. Therefore it is not necessary to presuppose for its action anything not produced by it.

And because every motion needs a subject–as Aristotle proves here, and is the truth of the matter–it follows that the universal production of being by God is neither motion nor change, but a certain simple coming forth. consequently, "to be made" and "to make" are used in an equivocal sense when applied to this universal production of being and to other productions.

Therefore, just as, if we should understand the production of things to be from God *ab aeterno*–as Aristotle supposed, and a number of the Platonists–it is not necessary, indeed it is impossible, that there have been a pre-existing but unproduced subject of this universal production, so also, in accord with the tenets of our faith, if we posit that He did not produce things *ab aeterno* but produced them after they had not existed, it is not necessary to posit a subject for this universal production.

It is evident, therefore, that what Aristotle proves here, namely, that every motion requires a mobile subject, is not against a tenet of our faith–for it has already been said that the universal production of things, whether *ab aeterno* or not, is neither a motion nor a change. For in order that there be motion or change, it is required that something be other now than previously, and thus there would be something previously existing, and consequently this would not be the universal production of things about which we are now speaking.

What Ibn-Rushd introduces about the early philosophers has no value, for they were unable to arrive at the first cause of all being but considered the causes of particular changes.

The first of these philosophers considered the causes solely of accidental changes, and posited all "being made" to be alteration. Those who succeeded them arrived at a knowledge of substantial changes, but those who came still later, such as Plato and Aristotle, arrived at a knowledge of the principle of all existence.

Consequently, it is clear that we are not moved to assert that something comes to be from nothing because we suppose only visible things to be beings; rather it is because we do not content ourselves with considering merely the particular productions of particular causes, but go on to consider the universal production of all being from the first principle of being. Nor do we assert that to need matter in order to act is due to a diminished power, in the sense of such a power's lacking its natural energy; rather, what we say is that this is proper to a particular power, which does not extend to all being but makes a particular being.

Hence one can say that it is characteristic of a "diminished power" to make something from something in the sense that we would say that a particular power is less than the universal power....

Regarding Aristotle's conclusion that motion always has been and will never cease

These, therefore, are the arguments by which Aristotle intends to prove that motion always has been and will never cease. The first part of which, i.e. that motion always existed, conflicts with our faith. For our faith admits nothing as eternally existing but God alone, who is utterly immobile–unless, of course, you wish to refer to the act of the divine intellect as a motion, but that would be an equivocal sense, and Aristotle is not here speaking of motion in that sense but of motion properly so called.

The other part of the conclusion is not entirely contrary to the faith, because, as was said above, Aristotle is not treating of the motion of the heavens in particular but of motion universally. Now we believe

according to our faith that the substance of the world indeed began, yet so as never to cease. For we posit that some motions will always exist, especially in men who will always remain, living an unceasing life either in happiness or misery...

If one rightly considers the arguments here given, the truth of the faith is not assailed by them. For they prove that motion did not begin through the way of nature, as some taught it did, but these arguments cannot prove that it did not begin by things being created by a first principle of things, as our faith holds. And that will be evident to anyone who considers each of the inferences here drawn by Aristotle.

For when he asks whether, if motion did not always exist, the movers and mobiles always existed or not, the reply must be that the first mover always existed; other things–movers or mobiles–did not always exist, but began to exist from the universal cause of all existence. But it has been pointed out above that the production of all being by the first cause of being is not a motion, whether this coming-forth be taken to be *ab aeterno* or not. Accordingly, it does not follow that before the first change there was a previous change. But this would follow if the movers and mobiles were newly brought into existence by some particular agent acting upon some presupposed subject that would be changed from non-being to being, or from privation to form–and Aristotle's argument concerns this way of coming into existence.

But because we posit that at least a first mover always existed, we need to give an answer to his subsequent deduction that, if movers and mobiles pre-exist, and motion begins newly to be in them, then the movers or mobiles could not have been previously in that disposition in which they are while there is motion, and therefore, some change must have preceded the first change.

Now, if we are speaking of the motion itself, the answer is easy: the mobiles were not previously in that disposition in which they now are, because previously they did not exist; hence they could not be moved. But, as it has been said, they received their existence not through a change or motion but through coming forth from the first principle of things; accordingly, it does not follow that before the first change there was a change.

But there still remains the question about the first production of things. For if the first principle, which is God, is no different now than before, then neither does he produce things now any more than before; but if he is different, at least the change affecting him will be prior to the change which is supposed to be the first. And indeed, if he were a cause that acts only through nature and not through intellect and will, this reason would conclude necessarily. But because he acts through will, he can through an eternal will produce an effect which is non-eternal, just as by his eternal intellect he can understand a thing that is non-eternal–the thing understood being in a certain way the principle of action in causes that act by intellect, as a natural form is in causes that act by nature.

But a further point must be pursued. For we do not say that a will postpones doing what it wants, unless something is expected in the future that does not yet exist in the present, as for example, when I will to make a fire not now but later, because in the future it is expected to be cold, on account of which I make the fire; or at least a presence of time is awaited. But that time succeeds time does not occur without motion. Therefore, it cannot be that a will, even if it be immutable, postpones doing what it wills, without some motion being involved. Accordingly, the new production of things cannot come forth from the eternal will except by means of motions succeeding one another *ad infinitum*.

Now those who raise this objection fail to see that it assumes a thing acting in time, i.e. something that acts on the assumption that time exists; for in this kind of action which occurs in time, one must consider some determinate relationship to this time or to things that exist in this time to explain why it be performed in this time rather than in some other time. But this reasoning has no place in the universal agent, which produces time itself at the same time that it produces other things.

For when we say that things have not always been produced by God, we do not understand that an infinite time preceded, in which God refrained from acting and that later, at a definite time, he began to

act; rather, we understand that God produced at once both time and things after they did not exist. Accordingly, we must not consider in the divine will that it willed to make things not then but later, as though time were already existing; rather, we must solely consider the fact that he willed that things and the time of their duration should begin to be after they had not existed at all.

If it be asked why he willed this, it must be said without a doubt that it was for his own sake. For just as he made things because of himself, in order that in them the likeness of his goodness be manifested, so he willed that they not always be, in order to show his self-sufficiency, from the fact that, although nothing else existed, he in himself had all sufficiency of happiness and of power to produce things.

And this can indeed be said as far as human reason can grasp divine things, saving, of course, the secret of divine wisdom which cannot be comprehended by us.

.. Aristotle assumed time to be eternal.. Yet, just as when we say that "outside" the universe there is nothing but God, we are not positing some dimension outside the world, so too, when we say that "before" the universe nothing existed, we are not positing any sort of successive duration before the universe.

tried to prove that immaterial substances exist and God is the cause of all existence. Likewise we read: “The

CHAPTER 13
THOMAS' WAYS, THREE TO FIVE

The argument from contingency

Scriptum super libros Sententiarum, I, d.3, q.1, a.1:

Thomas' commentary on the *Sentences* of Peter Lombard already has the three ways of knowing God in this life later propounded in his *Summa theologiae* (I, q. 12, a. 12): by causality, by removal, and by eminence. With regard to these he says:

1. The first reason is taken by way of causality, and takes this form: Everything that has being from nothing [i.e. from non-being, preceding generation] must exist by means of something from whom its being flowed. But all creatures have being from nothing, which is manifested from their imperfection and potentiality. Therefore they must exist by some first being, and this is God.

2. The second way is taken by way of removal, and is like this: Beyond every imperfect thing there most be something perfect which is not mixed with any imperfection. But a body is something imperfect, because it is limited and defined by its dimensions and is mobile. Therefore, beyond bodies, there must be something which is not a body. Likewise, every non-bodily thing which is changeable is imperfect by is very nature. Therefore, beyond all changeable species, such as souls and angels, there must be a being that is non-bodily, immobile and completely perfect, and that is God.

Summa contra gentiles, I, ch. 16 [7]

We see something in the world that emerges from potency to act. Now, it does not educe itself from potency to act, since that which is in potency, being still in potency, can therefore not act. Some prior being is therefore needed by which it may be brought forth from potency to act. This cannot go on to infinity. We must, therefore, arrive at some being that is only in act and in no wise in potency. This being we call God.

Summa contra gentiles, II, ch. 15 [4]

Then, too, the order of causes necessarily corresponds to the order of effects, since effects are commensurate with their causes. Hence, just as effects are referred to their appropriate causes, so that which is common in such effects must be reduced to a common cause. Thus, transcending the particular causes of the generation of this or that thing is the universal cause of generation–the sun; and above the particular governors of the kingdom, as, indeed, of each city in it, stands the king, the universal cause of government in his whole realm. Now, being is common to everything that is. Above all causes, then, there must be a cause whose proper action is to give being. But we have already shown in Book I that God is the first cause. Everything that is must, therefore, be from God.

Summa contra gentiles, II, ch. 15

(1) Now, because it has been proved that God is the source of being to some things, it must be demonstrated further that everything besides God derives its being from Him.

(2) For whatever does not belong to a thing a such appertains to it through some cause, as *white* to man; that which has no cause is primary and immediate, so that it must needs be through itself and as such. But no single entity can as such belong to two things and to both of them; for what is said of a thing as such is limited to that very thing; the possession of three angles equal to two right angles is proper to the triangle exclusively. So, if something belongs to two things, it will not belong to both as such. Therefore, no single thing can possibly be predicated of two things so as to be said of neither of them by

reason of a cause. On the contrary, either the one must be the cause of the other–as fire is the cause of heat in a mixed body, and yet each is called *hot*–or some third thing must be the cause of both, as fire is the cause of two candles giving light. But being is predicated of everything that is. Hence, there cannot possibly be two things neither of which has a cause of its being, but either both of them must exist through a cause, or the one must be the cause of the other's being. Everything which is in any way at all must then derive its being from that whose being has no cause. But we have already shown that God is this being whose existence has no cause. Everything which is in any mode whatever, therefore, is from Him. Now, to say that *being* is not a univocal predicate argues nothing against this conclusion. For *being* is not predicated of beings equivocally, but analogically, and thus a reduction to one must be made.

(3) Furthermore, whatever a thing possesses by its own nature, and not from some other cause, cannot be diminished and deficient in it. For, if something essential be subtracted from or added to a nature, another nature will at once arise, as in the case of numbers, where the addition or the subtraction of the unit changes the species of the number. If, however, the nature or quiddity of a thing remains integral, and yet something in it is found to be diminished, it is at once clear that this diminution does not derive simply from that nature, but from something else, by whose removal the nature is diminished. Therefore, whatever belongs to one thing less than to others belongs to it not by virtue of its own nature alone, but through some other cause. Thus, that thing of which a genus is chiefly predicated will be the cause of everything in that genus. So we see that what is most hot is the cause of heat in all hot things; and what is most light, the cause of all illuminated things. But as proved in Book I, God is being in the highest mode. Therefore, He is the cause of all things of which *being* is predicated.

Summa contra gentiles, II, ch. 43 [8]

Also, just as the act of being is first among effects, so, correspondingly, is it the proper effect of the first cause. But it is by virtue of form and not of matter that this act exists. Therefore, the first causation of forms is to be attributed above all to the first cause.

De potentia

q.3, a.3: Creation is not a motion leading up to a term, but a fact that is; thus creation is not a progress towards existence or a change by the Creator, but merely a beginning of existence and a relationship to the Creator from which the thing holds existence; thus creation is really nothing else than a relationship to God with a temporal beginning.

q.3, a.5: First, if in a number of things we find something that is common to all, we must conclude that this something was the effect of some one cause: for it is not possible that this common something belong to each one by reason of itself, since each one by itself is different from the others: and diversity of causes produces a diversity of effects. Seeing then that being is found to be common to all things, which are by themselves distinct from one another, it follows of necessity that they must come into being not by themselves, but by the action of some cause. Seemingly this is Plato's argument, since he required every multitude to be preceded by unity not only as regards number but also in reality.

q.3, a.14, ad 10: The action by which God brings things into being should not be understood to be like that of a workman who makes a box and then abandons it, but God continually sustains existence... Thus there is no need to suppose an instant when he made things, before which they were not made, apart for the reason that Faith tells us this is so.

q.6, a.6: Some of the philosophers of old contended that there was no such thing as an incorporeal substance and that all substances are bodies: and Augustine (*Confess.*) confesses that at one time he fell into this error. This opinion, however, was refuted by the philosophers. Aristotle rejected it (*Phys.* viii) for this reason that there must be some infinite moving power, since otherwise it would not produce a perpetual movement. Again he proves that every power of a magnitude must be finite whence it follows that there must be a power that is wholly incorporeal, in order to produce a continual movement.

Again he proves the same conclusion in another way (*Metaph.* xii). Act precedes potentiality both by nature and in time, absolutely speaking: although in this or that individual that passes from potentiality to act, potentiality precedes act in point of time. But seeing that it must be brought into actuality by something that is already actual, it follows that absolutely speaking act precedes potentiality even in time. Wherefore since every body is in potentiality, as its mutability shows, there must needs be an everlasting unchangeable substance that precedes all bodies.

A third argument in support of the same conclusion may be taken from the principles of the Platonists. Finite and, individual being must needs be preceded by a being that is infinite: thus if we find fire having a finite and so to speak participated nature in iron, we must expect to find the nature of fire in something that is fire essentially. Hence seeing that being and all other perfections and forms are found to have a finite nature in that they are received into matter, we infer that there must pre-exist an incorporeal substance wherein there is the perfection of being not in a finite mariner but with a certain universal fullness. The reason why they were led into the error of maintaining that all substance is corporeal was that their intelligence being unable to rise above their imagination whose object is wholly corporeal they were unable to reach the knowledge of incorporeal substances which the intelligence alone can grasp.

Read also q. 5, a. 1 (& ad 2 & 18).

Summa theologiae, I, q. 2, a. 3 [3]

The third way is taken from possibility and necessity, and runs thus: We find in nature things that are possible to be and not to be, since they are found to be generated and to corrupt, and consequently they are possible to be and not to be. But it is impossible for these always to exist, for that which is possible not to be at some time is not. Therefore, if everything is possible not to be, then at one time there could have been nothing in existence. Now if this were true, even now there would be nothing in existence, because that which does not exist only begins to exist by something already existing. Therefore, if at one time nothing was in existence, it would have been impossible for anything to have begun to exist; and thus even now nothing would be in existence–which is absurd. Therefore, not all beings are merely possible, but there must exist something the existence of which is necessary. But every necessary thing either has its necessity caused by another, or not. Now it is impossible to go on to infinity in necessary things which have their necessity caused by another, as has been already proved in regard to efficient causes. Therefore we cannot but postulate the existence of some being having of itself its own necessity, and not receiving it from another, but rather causing in others their necessity. This all men speak of as God.

The way that Thomas formulated his argument from motion in the *Summa theologiae* constitutes a bridge to the argument from contingency. That is because this argument also starts from motion and substantial change, but then, instead of looking for a series of proper causes, it takes this motion or change as a sign of a radical instability of all changeable things, such that they do not have existence from themselves but depend constantly on a necessary being to keep them in existence and operation. The commentary on the *Sentences* (1) expresses this as regards coming into being; the same commentary (2) expresses this as regards the continued duration of things. Both these arguments are summarized as one argument, stressing that existence as the most generic effect must come from the most general Cause, in the *Summa contra gentiles*, I, ch. 16 (the same thing looked at from God downwards in II, chs. 15 & 43) and *De potentia* (3, as coming from Ibn-Sînâ), and are succinctly presented in *Summa theologiae* (3).

The argument from degrees of perfection

Scriptum super libros Sententiarum, I, d.3, q.1, a.1:

(3) Two other reasons are taken by way of eminence. But eminence can be taken in two ways: as to being or as to knowing. Therefore the third reason is taken by way of eminence in being, and is like this: The good and the better are spoken of in reference to the best. But in substances we find that a body is

good and a created spirit is better, although it does not have goodness from itself. Therefore there must be something best from which exists the goodness in the first two.

(4) The fourth reason is taken by way of eminence in knowledge, and is like this: In whatever things can be found a greater and lesser degree of beauty, there is to be found a principle of beauty, by approximation to which one thing is said to be more beautiful than another. But we find that bodies are beautiful with a sensible form, while spirits are more beautiful with an intelligible form. Therefore there most by something from which each of them are beautiful, which created spirits more approximate.

Summa contra gentiles, I, ch. 13 [4]

In *Metaphysics* II [1, 993b 30] he shows that what is most true is also most a being. But in *Metaphysics* IV [4, 1008b, 31] he shows the existence of something supremely true from the observed fact that of two false things one is more false than the other, which means that one is more true than the other.

Summa contra gentiles, II, ch. 43 [9]

Furthermore, since every agent produces its like, the effect obtains its form from that reality to which it is made like through the form acquired by it; the material house acquires its form from the art which is the likeness of the house present in the mind. But all things are like God, who is pure act, so far as they have forms, through which they become actual; and so far as they desire forms, they are said to desire the divine likeness. It is therefore absurd to say that the formation of things is the work of anything other than God the Creator of all.

De potentia, III, a. 5

Later philosophers, such as Plato, Aristotle and their disciples, attained to the study of universal being: and hence they alone posited a universal cause of things, from which all others came into being, as Augustine states (*The city of God*, 8, 4). This is in agreement with the Catholic Faith, and may be proved by the three arguments that follow:

1. First, if in a number of things we find something that is common to all, we must conclude that this something was the effect of some one cause: for it is not possible that this common something belong to each one by reason of itself, since each one by itself is different from the others: and diversity of causes produces a diversity of effects. Seeing then that being is found to be common to all things, which are by themselves distinct from one another, it follows of necessity that they must come into being not by themselves, but by the action of some cause. Seemingly this is Plato's argument, since he required every multitude to be preceded by unity not only as regards number but also in reality.
2. The second argument is that whenever something is found to be in several things by participation in various degrees, it must be derived by those in which it exists imperfectly from that one in which it exists most perfectly: because where there are positive degrees of a thing so that we ascribe it to this one more and to that one less, this is in reference to one thing to which they approach, one nearer than another: for if each one were of itself competent to have it, there would be no reason why one should have it more than another. Thus fire, which is the extreme of heat, is the cause of heat in all things hot. Now there is one being most perfect and most true: which follows from the fact that there is a mover altogether immovable and absolutely perfect, as philosophers have proved. Consequently all other less perfect beings must derive being from him. This is the argument of the Philosopher.
3. The third argument is based on the principle that whatsoever is through another is to be reduced to that which is of itself. Wherefore if there were a *per se* heat, it would be the cause of all hot things, that have heat by way of participation. Now there is a being that is its own being: and this follows from the fact that there must be a being that is pure act, in which there is no composition. Hence from that one being all other beings that are not their own being, but have being by participation, must proceed. This is the argument of Ibn-Sînâ (*Comm. on Metaphysics*, 8, 6; 9, 8).

   Thus reason proves and faith holds that all things are created by God.

   Summa theologiae, I, q. 2, a. 3 [4]

> The fourth way is taken from the gradation to be found in things. Among beings there are some more and some less good, true, noble and the like. but "more" and "less" are predicated of different things, according as they resemble in their different ways something which is the maximum, as a thing is said to be hotter according as it more nearly resembles that which is hottest; so that there is something which is truest, something best, something noblest, and consequently something which is uttermost being; for those things that are greatest in truth are greatest in being, as it is written in *Metaphysics* II. Now the maximum in any genus is the cause of all in that genus; as fire, which is the maximum of heat, is the cause of all hot things. Therefore there must also be something which is to all beings the cause of their being, goodness and every other perfection; and this we call God.

All these ways look at what is imperfect, potential, finite and mobile as pointing to what is perfect, actual, infinite and immobile. They indicate a here-and-now dependence of the sensible and even the spiritual world upon what is Being itself, and do not refer to or depend on the cosmological assumptions of Aristotle (which Thomas nevertheless accepted).

While the argument of contingency focuses on the limited, labile and dependent existence of things, the argument from degrees of perfection focuses on limitation found in the essences of things, manifesting this by comparing things which vary in perfection. The commentary on the *Sentences* (3) shows that things which are imperfect with regard to being or (4) [= *Contra gentiles*, I, ch. 13 (4)] beauty and truth (because of potentiality) depend on something which has these perfections perfectly and independently of all else. *Summa contra gentiles*, II, ch. 43 presents briefly Thomas' teaching that God is the creator of all species (whereas individuals are simply the proper causes of multiplication of individuals within the species).

The very fact of diversity of being in the world, as argued in *De potentia* (2, repeated because it applies to both ways 3 & 4), following Plato, implies limitation and imperfection; all these scattered perfections, then, must be found united in one perfect being. The fact that in every category there are degrees of perfection, as argued in *De potentia* (2), following Aristotle, points to the same limitation and dependence on a perfect being. The same arguments are presented in *De potentia* (3) looking from God downwards. All these lines of thought are summarized in *Summa theologiae* (4).

The argument from purpose or design

De veritate, q. 5, a. 2

Providence is concerned with the direction of things to an end. Therefore, as the Commentator [Ibn-Rushd] says, whoever denies final causality should also deny providence... In that case all the harmony and usefulness found in things would be the result of chance. This was actually what Empedocles held. He asserted that it was by accident that the parts of animals came together in this way through friendship–and this was his explanation of an animal and of a frequent occurrence! This explanation, of course, is absurd, for those things that happen by chance, happen only rarely; we know from experience, however, that harmony and usefulness are found in nature either at all times or at least for the most part. This cannot be the result of mere chance; it must be because an end is intended. What lacks intellect or knowledge, however, cannot tend directly toward an end. It can do this only if someone else's knowledge has established an end for it, and directs it to that end. Consequently, since natural things have no knowledge, there must be some previously existing intelligence directing them to an end, like an archer who gives a definite motion to an arrow so that it will wing its way to a determined end. Now, the hit made by the arrow is said to be the work not of the arrow alone but also of the person who shot it. similarly, philosophers call every work of nature the work of intelligence.

Consequently, the world is ruled by the providence of that intellect which gave this order to nature; and we may compare the providence by which God rules the world to the domestic foresight by which a man rules his family, or to the political foresight by which a ruler governs a city or a kingdom, and directs the acts of others to a definite end. There is no providence, however, in God with respect to himself, since whatever is in him is an end, not a means to it.

Summa contra gentiles, I, ch. 13 [5]

Damascene proposes another argument for the same conclusion taken from the government of the world. Ibn-Rushd likewise hints at it. The argument runs thus: Contrary and discordant things cannot, always or for the most part, be parts of one order except under someone's government, which enables all and each to tend to a definite end. but in the world we find that things of diverse natures come together under one order, and this not rarely or by chance, but always or for the most part. There must therefore be some being by whose providence the world is governed. This we call God.

Summa theologiae, I, q. 2, a. 3 [5]

The fifth way is taken from the governance of the world. We see that things which lack intelligence, such as natural bodies, act for an end, and this is evident from their acting always, or nearly always, in the same way, so as to obtain the best result. Hence it is plain that not fortuitously, but designedly, do they achieve their end. Now whatever lacks intelligence cannot move towards an end, unless it be directed by some being endowed with knowledge and intelligence; as the arrow is shot to its mark by the archer. Therefore some intelligent being exists by whom all natural things are directed to their end; and this being we call God.

The fact that things that have no intelligence act for intelligible purposes defined in their natures points to an intelligence that designed their natures and keeps them operating according to the intelligent purpose he has set for them. This argument is set out in *De veritate*, *Contra gentiles* (5) and *Summa theologiae* (5).

The argument from design is based on three quite distinct phenomena: One is the design found in composition and form of things, particularly complex things, like the design of an eye or of the human body. Secondly there is the design found in the operation of natural things for their own survival, whether we look at something so basic as gravity or the behaviour of plants and animals to ensure the survival of their species. Thirdly there is the design found in the interaction of diverse things in the world to form a harmonious ecological system; for instance, it is natural for a banana plant to produce bananas (the second type of design), but that bananas should be food for animals and men is an extrinsic purpose accidental to the banana plant, but part of a cosmic design, which we call God's providence.

13.4 Critique of these other arguments

All of these arguments, just like that from motion, are based on the potentiality and, hence, limitation and dependency of things. The different "ways" are not different arguments, but simply ways of looking at the various manifestations of potentiality. That of contingency points at the potentiality of essence to existence. Those of degrees of perfection and design point at limitations within the essences of things. These arguments do seem valid, and make up for the weakness of the argument from motion, based as it is on a Ptolemaic universe with no notion of impetus in the movement of heavenly bodies.

Thomas says at the conclusion of his commentary on the *Metaphysics* that "Aristotle's conclusion is that there is one ruler of the whole universe, the first mover, and one first intelligible object, and one first good, whom he called God, who is blessed for ever and ever. Amen." We have seen that Aristotle may not have been so successful as Thomas would like to believe, but where Aristotle failed, Thomas succeeded.

A unique approach: *Lectura super Ioannem*, Prooemium (four ways)

I saw the Lord seated on a high and lofty throne, and the whole house was full of his majesty, and the things that were under him filled the temple. (Is 6:1)

Quidam enim per auctoritatem Dei in ipsius cognitionem pervenerunt; et haec est via efficacissima. Videmus enim ea quae sunt in rebus naturalibus, propter finem agere, et consequi utiles et certos fines; et cum intellectu careant, se ipsa dirigere non possunt, nisi ab aliquo dirigente per intellectum dirigantur et

3 Some attained to a knowledge of God through his authority, and this is the most efficacious way. For we see the things in nature acting for an end, and attaining to ends which are both useful and certain. And since they lack intelligence, they are unable to direct themselves, but must be directed and moved by one directing them, and who possesses an

moveantur. Et hinc est quod ipse motus rerum naturalium in finem certum, indicat esse aliquid altius, quo naturales res diriguntur in finem et gubernantur. Et ideo cum totus cursus naturae ordinate in finem procedat et dirigatur, de necessitate oportet nos ponere aliquid altius, quod dirigat ista et sicut dominus gubernet: et hic est Deus. Et haec gubernandi auctoritas in verbo Dei demonstratur, cum dicit dominum; unde in Ps. LXXXVIII, 10 dicitur: tu dominaris potestati maris; motum autem fluctuum eius tu mitigas; quasi dicat: tu es dominus et universa gubernas. Hanc cognitionem manifestat Ioannes se habere de verbo, cum dicit: in propria venit, scilicet in mundum; quia totus mundus est suus proprius.

Alii vero venerunt in cognitionem Dei ex eius aeternitate. Viderunt enim quod quicquid est in rebus, est mutabile; et quanto aliquid est nobilius in gradibus rerum, tanto minus habet de mutabilitate: puta, inferiora corpora sunt secundum substantiam et secundum locum mutabilia; corpora vero caelestia, quae nobiliora sunt, secundum substantiam immutabilia sunt; secundum autem locum tantum moventur. Secundum hoc ergo evidenter colligi potest, quod primum principium omnium rerum, et supremum et nobilius, sit immobile et aeternum. Et hanc aeternitatem verbi propheta insinuat, cum dicit sedentem, idest absque omni mutabilitate et aeternitate praesidentem; Ps. c. XLIV, 7: sedes tua, Deus, in saeculum saeculi; Hebr. ult., 8: Iesus Christus heri et hodie, ipse et in saecula. Hanc aeternitatem Ioannes ostendit dicens: in principio erat verbum.

Quidam autem venerunt in cognitionem Dei ex dignitate ipsius Dei: et isti fuerunt Platonici. Consideraverunt enim quod omne illud quod est secundum participationem, reducitur ad aliquid quod sit illud per suam essentiam, sicut ad primum et ad summum; sicut omnia ignita per participationem reducuntur ad ignem, qui est per essentiam suam talis. Cum ergo omnia quae sunt, participent esse, et sint per participationem entia, necesse est esse aliquid in cacumine omnium rerum, quod sit ipsum esse per suam essentiam, idest quod sua essentia sit suum esse: et hoc est Deus, qui est sufficientissima, et dignissima, et perfectissima causa totius esse, a quo omnia quae sunt, participant esse. Et huius dignitas ostenditur, cum dicitur super solium excelsum, quod, secundum Dionysium, ad

intellect. Thus it is that the movement of the things of nature toward a certain end indicates the existence of something higher by which the things of nature are directed to an end and governed. And so, since the whole course of nature advances to an end in an orderly way and is directed, we have to posit something higher which directs and governs them as Lord; and this is God. This authority in governing is shown to be in the Word of God when he says, **Lord**. Thus the Psalm (88:10) says: "You rule the power of the sea, and you still the swelling of its waves," as though saying: You are the Lord and govern all things. John shows that he knows this about the Word when he says below (1:11), "He came unto his own," i.e., to the world, since the whole universe is his own.

4 Others came to a knowledge of God from his eternity. They saw that whatever was in things was changeable, and that the more noble something is in the grades of being, so much the less it has of mutability. For example, the lower bodies are mutable both as to their substance and to place, while the heavenly bodies, which are more noble, are immutable in substance and change only with respect to place. We can clearly conclude from this that the first principle of all things, which is supreme and more noble, is changeless and eternal. The prophet suggests this eternity of the Word when he says, **seated,** i.e., presiding without any change and eternally. "Your throne, O God, is forever and ever" (Ps 44:7); "Jesus Christ is the same yesterday, today, and forever" (Heb 13:8). John points to this eternity when he says below (1:1), "In the beginning was the Word."

5 Still others came to a knowledge of God from the dignity of God; and these were the Platonists. They noted that everything which is something by participation is reduced to what is the same thing by essence, as to the first and highest. Thus, all things which are fiery by participation are reduced to fire, which is such by its essence. And so since all things which exist participate in existence (*esse*) and are beings by participation, there must necessarily be at the summit of all things something which is existence (*esse*) by its essence, i.e., whose essence is its existence. And this is God, who is the most sufficient, the most eminent, and the most perfect cause of the whole of existence, from, whom all things that are participate existence (*esse*). This dignity is shown in the words, **on a**

divinam naturam refertur; Ps. CXII, 4: excelsus super omnes gentes dominus. Hanc dignitatem ostendit nobis Ioannes, cum dicit: et Deus erat verbum, quasi: verbum erat Deus, ut ly verbum ponatur ex parte suppositi, et Deus ex parte appositi.

high throne, which, according to Denis, refer to the divine nature. "The Lord is high above all nations" (Ps 112:4). John shows us this dignity when he says below (1:1), "the Word was God," with "Word" as subject and "God" as the predicate.

Quidam autem venerunt in cognitionem Dei ex incomprehensibilitate veritatis. Omnis enim veritas quam intellectus noster capere potest, finita est; quia secundum Augustinum, omne quod scitur, scientis comprehensione finitur, et si finitur, est determinatum et particularizatum; et ideo necesse est primam et summam veritatem, quae superat omnem intellectum, incomprehensibilem et infinitam esse: et hoc est Deus. Unde in Ps. VIII, 2 dicitur: elevata est magnificentia tua super caelos, idest super omnem intellectum creatum, angelicum et humanum. Et hoc ideo, quia, ut dicit apostolus, lucem habitat inaccessibilem, I Tim. ult. 16. Huius autem incomprehensibilitas veritatis ostenditur nobis, cum dicit et elevatum, scilicet super omnem cognitionem intellectus creati. Et hanc incomprehensibilitatem insinuat nobis Ioannes, cum dicit: Deum nemo vidit unquam.

6 Yet others arrived at a knowledge of God from the incomprehensibility of truth. All the truth which our intellect is able to grasp is finite, since according to Augustine, "everything that is known is bounded by the comprehension of the one knowing"; and if it is bounded, it is determined and particularized. Therefore, the first and supreme Truth, which surpasses every intellect, must necessarily be incomprehensible and infinite; and this is God. [Hence the Psalm (8:2) says, "Your greatness is above the heavens," i.e., above every created intellect, angelic and human. The Apostle says this in the words, "He dwells in unapproachable light" (1 Tim 6:16). This incomprehensibility of Truth is shown to us in the word, **lofty,** that is, above all the knowledge of the created intellect. John implies this incomprehensibility to us when he says below (1:18), "No one has ever seen God."

Of these, the first ("most efficacious") way, "authority", corresponds with the 5th of the *Summa*'s five ways. The second way ("eternity") echos the contingency, or third way. The third way, "dignity", comes close to the *Summa*'s 4th way. The fourth way "incomprehensibility of truth" is new, but also approaches the 4th way of participation. Motion (*Summa*'s "most manifest" way) is not mentioned here.

J ATHANASIUS WEISHEIPL, OP.

NATURE AND GRAVITATION

ALBERTUS MAGNUS LYCEUM

Vidimus et approbavimus,

Romae, apud Pont. Institutum " Angelieum," die 15a mense Junii, anno 1953:

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Fr. EDWARDUS L. HUGHES, O. P., S. T. M.

Imprimatur:

* SAMUEL CARDINALIS STRITCH,

Archiepiscopus Chicagiensis,

Die 30a Septembris, 1955.

EXTRACTUM EX PERIODICO *The New Scholasticism* Vol. XXXVIII, 4 (1954), pp. 377-408 Vol. XXIX, 1 (1955), pp. 50-81 Vol. XXIX, 2 (1955), pp. 175-223

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INTRODUCTION

MOTION has always aroused wonder in the minds of thinking men throughout all centuries. Why does a body move? In particular, why does a body fall to the ground? Although gravitation is a fact of daily experience, the cause of this motion is very obscure. The great variety of explanations offered by the ancient Greek philosophers shows this obscurity.

Newton himself frequently acknowledged that he did not know the cause of gravitation.[1] Boyle and Hooke lamented that of all natural phenomena gravitation is the least explainable.[2] At the turn of the last century Karl Pearson admitted the difficulties of explaining why bodies move; he ended his discussion by saying that science can well afford to neglect the *why* and be content for the present to say: *Ignoramus.*[3] Even in our own day scientists who consider the problem clearly acknowledge that for all of science's progress in showing how bodies move, we still do not know *why* a body falls to the ground.[4] Of course, a great deal depends on what we mean by an "explanation." Scientific literature of the past few decades bears witness to the fact that modem science has become increasingly critical of its own methods and basic theories; and the very meaning

[11.] Newton, *Principia Mathematica,* Gen. Scholium, ed. F. Cajori, Berkeley, Calif. 1947, p. 547; see also Cajori's notes, pp. 632-635.

[2] Robert Boyle, *On the Usefulness of Experimental Philosophy,* P. I., *Works,* ed. Thomas Birch, London 1744, vol. III. Paper of R. Ilooke read to the Royal Society 1665, printed in Boyle's *Works,* vol. V, pp. 546-8; see also M. Boas, " The Establishment of the Mechanical Philosophy," *Osiris* X (1952), 412-541.

[S]K. Pearson, *The Grammar of Science,* London 1949, pp. 230-234.

[*] F. Cajori, notes to the *Principia, ed. cit.,* pp. 671, 665, 632-37; see also Cajori's *History of Physics,* N. Y., 1916, p. 62, note 1, and Sir Edmund Whittaker, *Prom Euclid to Eddington,* Cambridge 1949, pp. 112-4.

of " explanation " has undergone a change. Today it is necessary to consider every explanation in terms of a complete physical theory of nature, in terms of basic principles of reference.

After the time of Newton it was commonly thought that the problem of gravitation was conveniently disposed of by universal attraction. But the theory of Relativity in our own day forces us to face not only the problem of gravitation, but also the basic principles and assumptions of a physical theory which attempts to explain gravitation. The obligation of the Thomistic philosopher of nature is to join in the critical examination of physical theory and to help reconstruct a realistic theory of nature. It is idle for the Thomist to seek a *rapprochement* between Aristotelianism and pre-Relativity conceptions. The task today is a re-examination of all the principles of physical theory and an organic integration of human knowledge concerning the physical world.

The purpose of this dissertation is to re-examine those principles of physical theory which relate to gravitation as understood of both terrestrial and celestial movement. The method here employed is both historical and critical. Ernst Mach has amply shown the importance of an historical sense in examining physical theories. He wisely said, " One can never lose one's footing, or come into collision with facts, if one always keeps in view the path by which one has come." [5] But an historical sense alone will not build a true theory of nature. One needs also a critical sense in evaluating the logical and psychological foundations of scientific theories. The purpose of all such criticism is to produce an integrated unity in which all the parts make sense and are well established. To do this the fallacy of certain assumptions must be pointed out, the foundations of

*E. Mach, *History and Root of the Principle of the Conservation of Energy,* trans. by P. Jourdain, Chicago 1911, p. 17.

true principles must be established, and the necessary distinctions must be recognized. In the present problem of gravitation the desired organic unity of physical theory can be attained only by acknowledging an essential distinction between a strictly mathematical and a properly philosophical theory of nature. This is brought out by an historical examination of the main theories of gravitation which have been proposed throughout the centuries.

The thesis proposed in this dissertation can be expressed very briefly: Mathematical and philosophical theories of gravitation are two essentially distinct "explanations"; and the mathematical theory of Relativity can be corroborated only by a re-understood and re-vitalized Philosophy of Nature in the Aristotelian sense of the phrase. To defend this thesis it is necessary, first of all, to place the special problem of gravitation in the wider problem of motion itself, for without realizing this essential relevance the problem cannot be properly understood. In trying to solve this problem an analysis of the concept of ' nature ' must next be made, since the Aristotelian conception is frequently misrepresented and insufficiently analyzed, especially with regard to gravitation. The distinction between natural and compulsory motion must be examined, since it is commonly thought that such a distinction has been abolished by the principle of inertia. Finally a critical examination must be made of the principal modem theories of gravitation: Cartesian Vortices, Newtonian Attraction, and Einsteinian Relativity. Since no complete history of gravitational theories has yet been written, only the main outlines of the purely historical development can be indicated in this brief work. However, by means of the data available we hope to point out the historical and theoretical necessity of the thesis.

I would like to express my gratitude to the Very Reverend Edward L. Hughes, O. P., Provincial of the Province of St.

Albert the Great, for the opportunity to pursue graduate studies at the Angelicum and for his constant encouragement; to the Very Reverend Sebastian Carlson, O. P., Regent of Studies for the Province of St. Albert the Great; to the Reverend Bertrand W. Mahoney, O. P., who, as Professor of Natural Philosophy and as a close friend, directed the writing of this dissertation; and to the Very Reverend Vincent Ryan, O. P. Deep gratitude is due to Father Ambrose McNicholl, O. P., who in his lectures at the *Angelicum* profoundly illuminated the intimate relation between the physical sciences and modern philosophy. Mention must also be made of Fathers Thomas Kappeli, O. P., President of the Historical Institute at Santa Sabina; A. Donadaine, O. P., President of the Leonine Commission; D. A. Callus, O. P., Regent of Studies at Oxford; and of the librarians of the Bodleian Library and the Radcliffe Science Library at Oxford, the British Museum, London, and the Vatican Library. I also wish to acknowledge my gratitude to Dr. Vincent E. Smith, Editor of The New Scholasticism, for publishing three chapters of the dissertation and for permitting them to be reprinted here.

CHAPTER II

The Concept of Nature

WORDS can exercise a very strong tyranny over the mind, unless one realizes that words are merely a feeble medium in which to communicate our thoughts and oar experience of reality. Words are symbolic, not immediately of things, but of ideas; and those ideas ultimately involve a highly complex human experience of a reality which cannot be fully comprehended. There is, however, a common tendency, unconscious of course, to substitute words for the reality, thinking that in knowing the right word or phrase, we thereby know the reality we are talking about. This tendency is particularly dangerous in a philosophical tradition, in which words are carefully selected and definitions canonized. When such scientific terms and definitions are employed without sufficient analysis of meaning they deceive us into thinking we understand reality, while actually they are an impediment to true understanding. Modern philosophers, for the most part, shy away from traditional terminology for fear of being misunderstood or not understood at all. They tend to coin their own words, free of undesired implication, or juxtapose unexpected phrases to jolt the reader into seeing the meaning intended. Logical positivism has at least this merit that it insists on a careful analysis of meaning as a necessary factor in philosophical and scientific understanding.[1]

[1] Cf. A. Whitehead, *Modes of Thought* (Cambridge, Mass., 1938), pp. 1-171; also *Process and Reality* (New York, 1941), pp. 16-20.

The term "nature" has particularly suffered great abuse. In medieval thought the term was used in many senses, but each sense was clearly specified. Renaissance philosophy regarded nature as something divine and self-creative; it distinguished *natura naturata,* or the complex of observable changes and processes, from *natura naturans,* or the immanent force which animates and directs them. The Aristotelians whom Bacon, Boyle, and Newton attacked seemed to have avoided scientific research, claiming " nature " as a sufficient explanation of physical phenomena. While today the term has been applied in so many different senses, it seems to have no specific implication at all, much less is it an explanation. Therefore it is important that we analyze carefully the concept of nature to see its precise meaning.

In contemporary usage the term "nature" is on the whole most often used in a collective sense for the sum total or aggregate of natural things. We often speak of nature in the sense of the "universe" or "cosmos," meaning by that the whole of natural reality outside the mind. This sense implies a bifurcation of mind and external reality, which can be misleading. But the important point is that this notion of " nature " signifies something global and self-contained; it is a *nomen abso- lutum.* Even when we refer to the "nature" of man, of law, or any other reality, our reference is usually to its essence in the static sense of what makes it to be what it is. In other words, the ordinary use of the term " nature " is by no means a functional one, but rather a static and self-contained term. It is synonymous with "essence," or *quod quid est.* At the same time, this is not the only sense in which the word is used in modem languages. There is another sense, which we recognize to be its original and, strictly, its proper sense: when it refers not to a collection, but to a *principle,* or *source.* We often say that a man has an affectionate or quarrelsome nature, meaning that the man's own temperament in some way accounts for his

expression of affection or irascibility. We say it is the nature of water to flow down hill, the nature of dogs to bark. In this sense the word " nature " refers to something intrinsic which is responsible for the behavior. This is more clearly implied in the common distinction between natural behavior, that is, behavior resulting from something intrinsic to the thing itself, and compulsory, which arises from external constraint contrary to its proper activity. "Nature" as used in this sense of an intrinsic source is a *relative* term, that is, it is spoken of and thought of always in relation to a characteristic behavior or property. There is a great difference between these two senses. The absolute term merely connotes existence. The relative term, on the other hand, always implies source and responsibility. Although both senses are used in English, it is easy to see that the relative use of the term is prior and logically, as well as etymologically, would antecede its use in the absolute sense.[2]

Early Greek philosophy employed the term *phusis,* from which we derive our word " physics "and its variants, only in the relative sense of a source, or *arche.* Not until relatively late is the term employed in the secondary sense of an aggregate of natural things, that is, more or less synonymous with the word *lcosmos.*[3] The term *phusis* originally seems to have meant the process of generation, but the existing fragments of the pre- Socratics invariably employ the term to signify the " source " of the process. The Ionians, for example, were principally concerned with finding the original material " out of which " the entire universe is formed, an original source which would ex

[2] Cf. R. G. Collingwood, *The Idea of Nature* (Oxford, 1945), pp. 43-48.

[3] For example Gorgias, the famous Sicilian of the late 5th century, wrote a treatise entitled *PERI TOO MU 'ONTOS, 0 PERI PH08EOS-,* from what Sextus tells us, it is clear that *phusis* does not mean a principle but merely the world of nature; for Gorgias maintained: 1) that nothing exists; 2) if anything exists, it is incomprehensible; 3) if it is comprehensible, it is incommunicable. Cf. H. Diels, *Fragmente der Vorsokratiker,* 5th ed. (Berlin, 1934-8), 82 B, frag. 3. References to Diels abbreviated to *Vorsok.*

plain the evident phenomena of various movements in the universe. The single element of fire, air, or water was regarded by the Ionians as the true " nature " of things; it was the ultimate reality responsible for activity. Empedocles, realizing the insufficiency of a single element, regarded the four elements as the true nature of things. He makes a point of insisting that only those four elements should be called *phusis,* and reprimands his contemporaries who apply the term even to mixtures of these elements/ It is very important to remember that the pre-Socratic problem was the search for an ultimate explanation of sensible phenomena, and not merely a question of the "one" or the "many." The ultimate "one" postulated by the Ionians was not a static substratum, but a source, a *phusis* from which flows movement and sensible reality. Although the term was applied to a great many things, the essential connotation remained the same, namely, a material source of changing phenomena.[6]

* Diels, *Vorsok.,* 31 B, frag, 8.

[B] Over the past forty years a strong controversy has raged concerning the principal meaning of *phusis* among the pre-Socratics. Cf. summary in A. Mansion, *Introd. a la Physique Aristotilicienne,* 2nd ed. (Louvain, 1945), pp. 59-63; also bibliography in W. A. Heidel, " Perl phuseos, A study of the conception of Nature among the presocratics," *Proceed, of the Am. Acad, of Arts and Sciences,* XLV, n. 4, p. 96, note 69. The main point of the controversy seems to be whether the term primarily signified the eternal primary material of which the world is made Burnet, *Early Greek Philosophy,* 4th ed. (London, 1945), pp. 10-11; Appendix, pp. 363-4) or the universal process of growth W. A. Heidel, *op. cit.*; W. B. Veazie, " The Word PHUSIS," in *Archiv filr Gesch d. Philos.,* Bd, XXXIII, H. 1/2 (1926), 3-22. Mansion attempts to harmonize the opposing positions by insisting that " pour les penseurs anWrieurs *b,* Socrate la *phusis* cosmique englobait l'ensemble des pMnom^nes naturels, dont le monde est le theatre avec la r£alit6 materielle primitive, source et origine de ces ph6nom4nes " (*op. cit.,* p. 63). It would seem that the difficulty depends upon accepting or rejecting Aristotle's claim *(Metaph.,* V, c. 4, 1014bl7), that the term originally signified the process of birth, and then transferred to designate the source of this process. Cf. below p. 384, note 22. If Aristotle's claim is correct, then *phusis* is a *relative term* designating the " source " but always connoting "movement"; this is not a compound sense, but a single relative sense. Then, too, although the pre-Socratics considered this source

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In a very famous passage of the *Laws* Plato accuses his predecessors and contemporaries of impiety and of leading young men away from the gods.[6] All other philosophers, he says, teach that this beautiful universe, the regularity of celestial movements, and the human soul arise " not because of mind, nor because of any god, nor by art, but as we may say, by *nature* and *chance."* [7] Plato recognizes that all things which come about in the universe are the result either of art (*techne*), nature *(phusis),* or chance (*tuche).*[8] But the ancient philosophers and even his own contemporaries attribute the origin of the universe and its phenomena to nature, a blind material element which operates by chance. He asks how was it that " nature " in the first place acquired movement and force to produce the order of the universe? How, he asks, can soul be a result of material *phusis,* since intelligence must be anterior in order to direct growth and order?[9] If *phusis* means the " first source," then the term should not be applied to fire, air, or earth, but to Soul *(psuche).*[10] For Plato it is Soul (God) which is the first source of all being and becoming, the ruler of the heavens, the law-giver.[11] The ancient philosophers who attribute all phenomena to nature, derogate from the rights of God, "Who is the true Nature, unseen by the senses of the body, but perceived by the intellect.[12] In his explanation of the ma-

(*phUsis*) to be "ageless and deathless," as Burnet points out (op. *cit.,* p. 10), it would seem that this eternal and absolute characteristic of *phusis* is a subsequent attribute of the One, which was called nature.

" Plato, *Laws* X, 884 A-913 D.

[7] *Laws* X, 889 B. Cf. Aristophanes, " Zeus is dethroned and Vortex *(ding)* reigns in his stead." *Clouds,* 828; see also Diogenes IX, 31-34, Diels, *Doxographi Graeci* (Berlin, 1929), pp. 142-3; and Burnet, *Early Greek Philosophers,* pp. 338-9, 341-7.

[8] *Laws* X, 888 E. Plato implies that this division was employed also by his adversaries, cf. also 889 C.

[9] *Laws,* 891 B-892 A.

[10] *Ibid.,* 892 C.

[11] *Laws,* 896 D-897 C.

[13] *Ibid.,* 898 D-E.

terial world Plato gives to art a preeminence over nature and chance. That is to say, Plato insists that the material universe is a product of the *art* of God.[ls]

Plato, however, does not use the term *phusis* consistently throughout his works, for sometimes he opposes the two classes of being, *phusis* and intelligence,[14] and sometimes he attributes the traditional role of *phusis* to Soul, maintaining that the use of the term to designate material elements must be absolutely condemned.[16] In fact, it must be admitted that Plato did not develop a doctrine of nature; rather he replaces the theory of nature by a theory of Soul.[16] His concern is to show that all material reality proceeds from divine intelligence, which necessarily must be anterior to the world. Furthermore, in the course of developing his arguments against his adversaries, he shows that all corporeal movement without exception depends upon the influences and direction of the Soul which permeates space.[17] Therefore, for Plato it is not nature which is primary in the explanation of physical reality, but the divine Soul which produces the world and directs movement by *art.*

Undoubtedly Aristotle had in mind Book X of the *Laws* when he developed his own doctrine of nature in Book II of the *Physics.* The threefold division of causes into nature, art, and chance is Plato's point of departure for attacking his adversaries. This same threefold division is Aristotle's starting point for rehabilitating the naturalist theories of the pre-Socratics in face of Plato's criticism. Whereas Plato, insisting on the priority of Soul, had rejected the idea of nature and attributed

[13] Aristotle himself employed this explanation in his early work, *De Philosophia,* where he represents the world as produced " by the very perfect art of God." V. Rose, *Fragmenta,* Biblioth. Teubneriana (Leipzie, 1886), frag. 21.

[14] Cf. *Apol.,* 22 C.

[15] *Laws,* X, 892 B-C.

A. Mansion, *op. cit.,* p. 83.

[17] *Laws,* X, 899 D ff.

most of the characteristics of *phusis* to Soul, Aristotle tried to maintain both the priority of Soul and the reality of " nature." Before analyzing Aristotle's idea of nature, it is necessary to consider the passage in Book V of the *Metaphysics* where he discusses the various meanings of the word *phusis.*[19] In this philosophical lexicon, probably an earlier work than the Second Book of the *Physics,*[19] Aristotle intends to explain the various senses in which the word is used. Realizing that different senses of the same word are somehow related, he attempts to show the primary sense of the word and how other senses are related to it. He lists six principal meanings of the term *phusis;* these he reduces to one which is the primary and strict sense.[20] For Aristotle the primary and strict sense of the term *phusis* is a formal, or active principle of movement and rest in all corporeal reality.

1) Aristotle tells us that the word originally meant "the genesis of growing things—the meaning which would be suggested if one were to pronounce the *u* in *phusis* long." That is to say, the word is probably derived from *phuo* which has *u* long in most of its forms, so that the connotation of *phusis* is that of a process. It is impossible to convey this sense in English, but there is a similarity in Latin for it seems that *natura* originally signified *nativitas.*[21] For Aristotle, then, *phusis* originally meant the process of growing.[22]

[18] Arist., *Met.,* V, c. 4, 1014bl7-1015»19.

[19] This is the opinion of Zeller and Jaeger; cf. Zeller, *Die Phil. d. Grie- chen* (Leipzig, 1879), II, 2, 157. But W. K. C. Guthrie has presented some strong arguments in favor of a very late composition; cf. *Classical Quarterly,* XXVII (1933), 162-71; XXVIII (1934), 90-98.

[20] Arist., *Met.,* V, c. 4, 1014>>17-1015[a]19. St. Thomas very frequently lists and discusses the analogy of these different senses, especially *In V. Met.,* 5, nn. 808-826; *In III Sent.,* d. 5, q. 1, a. 2; *Sum. cont. Gent.,* c. 35; *De Unione verbi Incarnati,* a. 1; *Summa Theol.,* I, 29, 1 ad 4.

[21] " Fundamentally *natura* signified 'birth' (as in Terence, *Ad.,* 126, 902), i.e., the process by which living objects come into being." *Hasting's Encyclopedia of Religions and Ethics* (Edinburgh, 1917), IX, 244b.

[a]* Burnet, however, doubts *(op. cit.,* pp. 10-12; 363-364) that *phusis* ever

2) From the activity of growth, the word was transferred to signify the active principle of growing things. St. Thomas explains this by saying that " active powers are customarily named from the activities." [23]

3) Then the term was extended to signify "the source of the primary movement in each natural object which is in it in virtue of its own essence *(onsia),"* [2i] that is, it signifies *the active 'principle of movement in all natural things.* That Aristotle means here the *active* source of each body's characteristic movement is clear from his example of growing things.[25]

4) But this sense of *phusis,* as we have seen, was first applied to " the primary material out of which any natural object is made." [26] Aristotle notes that some have called it fire, others earth, others air, others water, others something else of the sort, and some named it more than one of these, and others all of them.[27]

5) But *phusis* was soon applied also to the form and total composition of natural objects. We have seen that the earliest

had this meaning, as he has been unable to find this exclusive sense in any of the pre-Socratic fragments. He is followed in this by Lovejoy in the *Philosophical Review,* XVIII (1919), 369 ff., as well as by Sir David Ross (*Aristotle's Metaphysics* [Oxford, 1924], I, 296-298) and by R. O. Colling- wood *(The Idea of Nature* [Oxford, 1945], pp. 80-81). This specialized difficulty must be left to the scholars. But it must be admitted that the word at least had this connotation, as we can see from Plato's use of *genesis* in *Laws* X, 892 C and Aristotle's strange arguments from Antiphon, in *Phys.,* II, c. 1, 193al2-17, 193b8-13.. Considering the origins of human language there is no reason to suppose that such a connotation is not indicative of the original sense Aristotle mentions.

[23] ". . . quia virtutes agentes ex actibus nominari conseuverunt." *In III Sent.,* d. 5, q. 1, a. 2; cf. *In V Met.,* 5, n. 809.

[2*] Arist., *Metaph.,* 1014bl9-20.

[25] Cf. also St. Thomas: " Inde ulterius processit nomen naturae ad significandum principium activum cuiuslibet motus naturalis." *In III Sent.,* d. 5, q. 1, a. 2; " Et haec est definitio posita in II Physicorum." *In V Met., 5,* n. 810.

[*•] Arist., Met., 1014b27-28.

[27] *Ibid.,* 1014b32-35.

philosophers wanted to restrict the term *phusis* to the elements, but Empedocles, quoted by Aristotle on this point, acknowledges that men give the name even to mixtures.[28] It is really this sense of *phusis* that Aristotle develops in his philosophy of nature. The background of this must be understood in the light of his frequent attack on the pre-Socratics in that they considered only matter to be " substance," failing to distinguish between " first matter " and the material substance.[29] As the pre-Socratics were unable to explain essential changes, the immutable matter was " substance," to which they applied the idea of *phusis;* the composition (form), although theoretically only a mixture, was nevertheless called *phusis* by ordinary men.[30] Aristotle's explanation of substantial change allows him to justify and to develop this common use of " nature " as the specifying form of bodies which manifest characteristic activities.

6) Finally " by an extension of meaning from this sense of *phusis* every essence in general has conte to be called a nature." [31] This is the static sense of nature as " the essence, which the definition signifies," [32] or " the informing specific difference in each and every thing." [33] In this transferred sense *phusis* is a *nomen absolutum,* quite different from the preceding

[28] Diels, *Vorsok.* 31 B. frag. 8. For the exegesis of this passage cf. Burnet, *op. cit.,* pp. 205-6, note 4.

[29] Cf. Arist., *Metaph.,* I, c. 3, 983b6-19; c. 7, 988al8-b22; VII, c. 3; cf. also St. Thomas, *In VII Met.,* 2, nn. 1281-1293, where he develops this idea very clearly.

[s°] Diels, *Vorsok.,* 31 B, frag. 8. St. Thomas explains: " Decipit autem antiquos philosophos hanc rationem inducentes, ignorantia formae sub- stantialis. . .. . Forma autenj substantialis non est sensibilis nisi per accidens; et ideo ad eius cognitionem non pervenerunt. Sed totum subiec- tum, quod nos ponimus ex materia et forma componi, ipsi dicebant esse primam materiam, ut aerem, aut aquam, aut aliquid huiusmodi. Formas autem dicebant esse, quae nos dicimus accidentia. . . ." VII *Metaph.,* lect.
2, n. 1284.

[S1] Arist., Met., 1015all-12.

[32] Cf. St. Thomas, *Sum. con. Gent.,* IV, 35.

[28] Boethius, *De Dual. Nat.,* PL 64, 1341.

uses. In his *Commentary on the Metaphysics* St. Thomas does not list this among the principal significations of the word, but as an extension "secundum quamdam metaphoram." [84] Considering these various senses, Aristotle concludes, "It is plain that nature in the primary and strict sense is the essence of things which have in themselves, as such, a source of movement." [36] But matter, too, can be called nature, "because it is qualified to receive this." [88]

In the *Metaphysics* Aristotle presents all of this without proof or elaboration. He is concerned only with classifying the various meanings of the term "nature" and in pointing out the primary meaning. However, Aristotle's own position in the history of Greek thought is very clear from this passage. It is mainly in Books II and VIII of the *Physics* that he justifies and elaborates his conception of nature as an intrinsic principle of movement.

The Aristotelian conception of nature must be understood in contrast to art and chance. We have already seen that this tripartite division was commonplace at the time of Plato. By art is meant any production by human intelligence, anything produced by the human mind acting upon reality.[37] By this is meant not only pictures, statues, machines, and other works of craftsmanship, but every result of human interference, such as pushing, pulling, throwing, twirling, holding, and so forth. In other words, a stone which is thrown into the air would not be considered to move upward naturally, but to be the result of "art." This does not mean that every human action on the physical world is "artistic," or "intelligent," but that there

[34] *In V Met.,* 5, n. 823; but in parallel places St. Thomas lists all the senses together as analogically similar,

[85] Arist., *Met.,* 1015al3-15.

"Ibid., 1015al5-16.

[87] Plato seems to have been the first to apply "art" to the activity of divine intelligence in the world. But in the present context Aristotle means to discuss only the work of human intelligence.

are phenomena in the world which *can be accounted for* as the work of human activity. Besides the result of human activity, there are many phenomena which are the result of mere *chance,* or accident. Chance is the irrational element in the world. Certainly after a chance event has occurred the phenomenon can be explained rationally as the concurrence of such and such a factor. But the event itself is unpredictable; it is the unexpected, the unintended. Just as in human experience many things happen merely by chance, so too in the physical world many events are the result of two factors, each of which has its own history. But every result of chance presupposes factors which have an individual history, a make-up and intelligibility which are proper to each. That is to say, just as not every phenomenon can be explained by human control, so neither can every phenomenon be explained by chance. For chance is not a thing, but a concurrence; and every concurrence involves things.[88] Therefore some agent other than "art" or "chance" is necessarily operative in the universe; for convenience this agency may be called *nature.*

From what has been said it is clear that human activity in the world and chance both presuppose phenomena which cannot be accounted for by either of them. Human activity presupposes not only the existence of things and phenomena upon which to work, but even a qualitative differentiation which must be acknowledged. For example, an artist cannot make a statue out of air, nor can an aviator fly through the earth.

*[8] Chance plays a very large role in the Aristotelian view of the universe, but Aristotle is careful to point out that chance as such is the *meeting* of particular bodies, and indeed, the meeting of *individual* bodies. That is to say, such a meeting is not within the intentionality of any particular body (cf. *Phys.,* II, c. 5-6). Thus he defines chance as a "causa per accidens" (Phys,, II, c. 5, 197a5-6), meaning that the event is *not intended* by either factor. St. Thomas insists that nowhere within the whole physical universe is there a cause which per *se* intends the chance event, concursus; cf. *Sum. cont. Gent.,* Ill, 86; c. 93; *Summa Theol.,* I, 115, 6; 116. Chance is not to be understood here as "probability."

There are, in other words, objective phenomena which must be recognized before they can be utilized by man. The results of chance also presuppose the concurrence of qualitatively different phenomena each with its own characteristics, and functioning according to its own determined laws. It is only the simultaneity of definite factors which result in an explosion, the birth of a monster, or a devastating cyclone. Chance results are irrational precisely because they involve the meeting of qualitatively different phenomena, each acting according to its own laws.

The fundamental assumption in the Aristotelian conception of nature is that natural phenomena, that is, those arising from neither art nor chance, are intelligible; there is a regularity, a determined rationality about these phenomena which can be grasped. This must be the basic assumption of all science, for without it science itself is impossible.

When the great variety of " natural " phenomena has been classified scientifically, their individual characteristics and laws noted, we are still left with the question of their radical source, the ultimate accountability of all such phenomena. Even the action and reaction of various elements, the variation of circumstances, the intricate dependencies and interplay of everything from electrons to cosmic rays still leave the question of *source* unanswered. What is the source of any of this activity? It does not make much difference what name is applied The important thing is that we must in the last analysis acknowledge a certain *internal spontaneity* in all things from the smallest to the largest in the universe. When one considers, for example, the great variety of activities proper to chemical elements, electrons, and other physical bodies, the phenomena of illumination and ultra-violet rays, one can only say that they proceed automatically and spontaneously from the bodies themselves. There can be no other " source " for characteristic activities, except internal spontaneity. Obviously these phenomena

are not the result of chance; this is precluded by a regularity and constancy which can even be measured. Nor can it be said that such movement is acquired from something else, for experience shows that even the transmission of activity depends essentially on the internal disposition and " willingness " of each body in view of its proper activity; thus not all bodies can be acted upon in the same way. Therefore, we must admit that in each physical reality there is something ultimately *given* in experience, which is none other than the spontaneous manifestation of its characteristics and proper activities. There is nothing " behind " this spontaneity, as far as the body is concerned; it is just "given" in experience. All the factors involved in the event must be considered, the circumstances of variation, intensity, prevention, and so forth, but in the last analysis there is the spontaneity " given," as from the body itself. Together with this spontaneity there are also certain receptivities for external influence, receptivities which are compatible with the spontaneous characteristics of each body. To both of these intrinsic sources, the spontaneous and the receptive, Aristotle gives the name *nature,* which he defines as *"* the principle of movement and rest in those things to which it belongs properly (per *se*) and not as concomitant attribute (per *accidens).*"[39]

Fundamentally this is Aristotle's procedure, but more specifically, he draws a comparison between natural and artificial bodies.[40] Natural bodies come into being through natural agencies; artificial bodies are produced by man. Moreover, the essential difference between them is that natural bodies *do* some-

" This definition (*Phys.,* II, c. 1, 192b21-3) is repeated, more or less complete, in various works of Aristotle: *Phys.,* Ill, c. 1, 200bl2-13; VIII, c. 3, 253b5-6; c. 4, 254bl6-17; *De Coelo,* I, c. 2, 268bl6; III, c. 2, 301bl7- 18; *De Anima,* II, c. 1, 412bl5-17; *De Gen. Animal.,* II, c. 1, 735a3-4; *Metaph.,* VI, c. 1, 1025b20-21; IX, c. 8, 1049b8-10; XII, c. 3, 1070a7-8; *Ethic. Nic.,* VI, c. 4, 1140a5-6; *Rhet.,* I, c. 10, 1369a35-bl.

[40] Arist., *Phys.* II, c. 1, 192b8-32.

thing: some grow and decay, others move and manifest activities, and so forth. But artificial compositions merely exist as an expression of an idea. Whatever " activity " there is about an artificial composition is the result, not of the artistic as such, but of the natural elements of which it is composed; or it is the result of calculated compulsion. For example, a painting falls to the ground, burns, or decays, not because it is a painting, but because of the materials of which it is made. Everyone realizes that the movement of a watch or mechanical doll does not come about spontaneously, but from a spring which is wound by the user. Therefore, Aristotle concludes that the difference between natural and artificial things is that natural things have within themselves an intrinsic source of movement and rest, " in virtue of itself and not in virtue of a concomitant attribute." [41]

For Aristotle, then, nature is this intrinsic source of characteristic movement. Things " have a nature " or are " natural " which have such a principle. He insists that, " each of them is a substance, for each is a subject; and nature always implies a subject in which it inheres." [42] Mansion notes that, " C'est l'expression du realisme peripateticien, qui veut accorder une realite aux principes abstraits, mais a condition de ne la recon- naitre que dans un substrat materiel dont ils sont separables

[41] Arist., *Phys.,* II, c. 1, 192b22-23.

[4a] *Ibid.,* 192b33-34. The punctuation here used is that of Hamelin (Aris- tote, *Physique* II, pp. 40-41) and Mansion (op. *cit.,* p. 100) which is suggested by the paraphrase of Themistius and Philoponus. This seems to be clearer than the usual reading given by Bekker, Didot, and Ross: " Each of them is a substance; for it is a subject, and nature always implies a subject in which it inheres" (Ross trans. *Basic Works,* p. 236). On the basis of this usual punctuation, also employed by William of Moerbeke, St. Thomas finds it necessary to give this interpretation: "Et talia sunt omnia subiecta naturae: quia natura est subiectum, secundum quod natura dicitur materia; et est in subiecto, secundum quod natura dicitur forma " *{In II Phys.,* 1, n. 6). But it seems that Aristotle does not have this in mind, for he has not yet shown that nature can be said of both matter and form; this he does in 193a9-21.

par la pensee seule." [43] In other words, Aristotle is insisting that if we wish to understand natural phenomena, we must admit an internal spontaneity (nature) within concrete bodies for their characteristic behavior. He is not appealing to an abstraction,[44] nor to anything outside the acting body. He is insisting that we see spontaneous activity and all we can say is that it *is* spontaneous; the source of characteristic spontaneity he calls " nature." Therefore he says, *that* such a reality exists is obvious, and it would be absurd to attempt any "proof." [45]

It has been shown that bodies in the universe manifest not only a certain " spontaneity " for characteristic behavior, but also certain " receptivities " for external influence. This leads Aristotle to point out that " nature " is used in two senses: as an *active* (spontaneous) principle and as a *passive* (receptive) principle.

In Book II of the *Physics* Aristotle is merely concerned with showing that the ancient use of *phusis* should be applied not only to the " matter " out of which things are made, but also, and more properly to the " form " of the thing itself. The ancients rightly attributed *phusis* to matter, but as they were unable to account for intrinsic change, " matter " for them meant the " substance " which was conceived as an *active* principle of behavior. Aristotle, relying on his doctrine of potency and act, insists that the true " matter " is antecedent to substance ; this " matter " is purely *passive,* being a pure potentiality for being (substance). Employing the analogy of art, he says, " We should not say that there is anything artistic about a thing, if it is a bed only potentially, not yet having the form of bed; nor should we call it a work of art." [48] Simi-

[48] A.. Mansion, *op. cit.,* p. 100.

** " Thus in the second sense of " nature " it would be the shape or form (not separable except in statement) of things which have in themselves a source of motion." Arist., *Phys.,* II, c. 1, 193b3-5.

" Arist., *Phys.,* II, c. 1, 193a2-8.

'e Arist., *Phys.,* II, c. 2, 193a33-35.

larly in natural products, " what is potentially flesh or bone has not yet its own ' nature,' and does not exist ' by nature,' until it receives the form specified in the definition, which we name in defining what flesh or bone is." [47] That is to say, nature as an *active* and spontaneous principle, which the ancients attributed to matter, properly applies to " form "; if the term is applied to " matter," it connotes passivity.

The scholastics developed to a considerable extent this twofold sense of nature as an active and as a passive principle. Nature as matter, or *natura secundum materiam* [48] signified not only the pure potentiality of the first matter, but all passivities of bodies which require a natural agent to actualize it. Nature as form, or *secundum principium formate,* signified the active and spontaneous source of all characteristic properties and behavior; ultimately this active principle was considered to be the " substantial form " which functions through active qualities.[48] Thus in scholastic terminology nature as "matter" is equivalent to *principium passivum, receptivum,* and *materiale*; while nature as " form " is equivalent to *principium activum,* or *formate.*[50] These two senses of " nature " in scholastic philosophy must be explained briefly.

[47] *Ibid.,* 193a36-b2.

[41] St. Thomas, *In II Phys.,* 1, n. 4.

*• Cf. St. Thomas, VII *Metaph.,* lect, 8, n. 1448; II *Sent.,* dist. 14, q. 1, a. 5 ad 2.

[80] The equivalence of *principium materiale* and *passivum* on the one hand, and *principium form ale* and *activum* on the other is very clear in St. Thomas: " Habet enim huiusmodi motus in mobili *principium,* non solum *materiale et receptivum,* sed etiam *formale et activum." (De Pot.,* V, 5) ; ". . . non est naturalis propter *activam inclinationem formalis prin- cipii* in corpore caelesti ad talem motum, sicut est in elementis " *(ibid.,* ad 12). "Non autem potest esse quod motus caelestis sequatur *formam* caelestis corporis sicut *principium activum* . . . sed solum *ratione principii passivi, quod est materia" (Sum. cont. Gent.,* Ill, 23). ". . . eonti'arietas motuum naturalium consequitur proprietatem *principiorum activorum sive formalium,* ad quae consequitur motus; non autem contrarietatem *principiorum passivorum sive materialium" (In De Coelo,* 16, n. 13; cf. Ill, 7, nn. 5-9). " Non enim oportet ad motum naturalem quod semper prin-

St. Thomas lays down the general principle that natural bodies have within them a principle of movement precisely to the extent to which they have motion: inasmuch as they spontaneously *move,* they have an " active " principle; and inasmuch as they must *be moved,* they have the " passive " principle, which is matter.[01] Experience alone can indicate whether bodies spontaneously act or are being acted upon by an external force.

I. Nature as Passive Principle

Some of the medieval writers, notably St. Albert, thought that " nature " always implies some *active* source, and that the term " natural " should be restricted to those phenomena which proceed more or less actively from the body. Since for St. Albert the movement of the heavens is caused by separated intelligences, such movement was not considered the work of nature, but of intelligence.[62] Even substantial change, according to him is " natural " in view of a certain incomplete active principle, an *inchoatio formae,* which assists the external agent.[63] St. Albert, however, does distinguish between " form "

cipium motus, quod est in mobili, sit *principium activum, et formale;* sed quandoque est *passivum et materiale" (In VII Met.,* 8, n. 1442z). This equivalence was also common to the 14th cent, scholastics, as Walter Burley testifies: " Primo quod cum dicitur quod naturalia inquantum huius- modi habent in Beipsis principium motus et status, ibi hoc nomen principium accipitur communiter *pro principio secundum materiam, idest, pro principio passivo,* et *pro principio motus secundum formam, idest, pro principio activo."* (Burlaei, *In Physicas Arist. Expositio et Quaestiones* (Venetiis 1501), Lib. II, fol. 36r col. 1.

" Et ideo dicendum est quod in rebus naturalibus eo modo est principium motus, quo eis motus convenit. Quibus ergo convenit movere, est in eis principium activum motus; quibus autem competit moveri, est in eis principium passivum, quod est materia " *In II Phys.,* 1, n. 4.

" St. Albert, *In II Phys.,* tr. I, cap. 2, (ed. Borgnet).

•* " Dicunt ergo quidam quod etiam in huiusmodi mutationibus [sub- stantialibus] principium activum motus est in eo quod movetur; non quidem perfectum, sed imperfectum, quod coadiuvat actionem exterioris agentis. Dicunt enim quod in materia est quaedam inchoatio formae, . . . et ab hoc principio intrinseco generationes corporum simplicium naturales dicuntur." St. Thomas, *In II Phys.,* 1, n. 3. The *quidam* here refers to St.

as the perfect active principle and " matter " as a passive potentiality, having only the beginning of form and requiring an external mover to actualize it fully.[5]*

St. Thomas, however, rejects the *inchoatio formae* as an impossibility.[55] He insists that for natural phenomena it is not necessary that all movement proceed from an active principle; natural receptivity itself is sufficient to render the motion " natural." [56] Consequently the celestial movements are natural because the heavenly bodies have a natural potentiality for being moved by spiritual beings. That is, if they are moved by intelligences, then it is natural to the celestial bodies to be moved.[57] And substantial generation is natural, because the pure potentiality of first matter is intrinsically capable of *being moved.*

Every body which is *acted upon* is in some sense passive, but this is not to be identified with " nature " as a passive principle. Three passivities must be distinguished: i)for compulsory movement; ii) for artistic formation; and iii) for natural production. A stone which is thrown into the air has a certain passivity for this motion, but as the motion itself is not natural,[58] neither is the potentiality. When an artist chooses his material, he must choose something suitable with which to work,

Albert and St. Bonaventure; cf. St. Albert, *In II Phys.,* tr. I, cap. 9; *Summa Theol.,* P. 2, tr. I, q. 4. *n.* 2, a. 1, p. 82; St. Bonaventure *(In II Sent.,* d. 18, a. 1, a. 3) ; and to Giles of Rome *(In Phys.,* II, lect.l, dub. 9).

[s]' Cf *In VIII Phys.,* tr. II, cap. 4. He defines the passivity of nature as " illud quod habet in se susceptivam et passivam potentiam recipiendi formam, sec. quam movet motor suus per inchoationem ipsius formae in ipso." *Ibid.*

[55] Cf. *In II Phys.,* 1, n. 3; *In VII Met.,* 8, n. 1442a-z.

[60] " Non enim oportet ad motum naturalem, quod semper principium motus, quod est in mobili, sit principium activum et formale; sed quan- doque est passivum et materiale." St. Thomas, *In VII Met.,* 8, n.l442z.

[57] " Et sic etiam motus localis corporum caelestium est naturalis, licet sit a motore separato, inquantum in ipso corpore caeli est potentia naturalis ad talem motum." St. Thomas, *In II Phys.,* 1, n. 4.

[58] This question will be taken up in a subsequent article: " Natural and Compulsory Movement."

as not all materials present the same possibilities. But since such potentialities are realized by art and not by nature, they are not properly called " natural." [58] In the strict sense, a " natural " potentiality is one which *intrinsically tends* toward perfect realization, and which can be actualized by a natural agent.[60] In other words, nature as a passive^ principle essentially implies an intrinsic *intentionality* of final realization, a receptivity which tends toward the *good* of the whole. That is to say, it implies first of all, the order of final causality. The actualization of a natural potentiality is not to be conceived as something superadded, like the addition of a number. Rather the potentiality itself intrinsically tends toward, aims at realization, just as the mind essentially tends toward knowledge. The scholastic philosophers called this an " appetite " and a "desire " for realization, which realization is its assimilation to being and perfection. Secondly, nature as a passive potentiality implies a capacity for realization by natural agencies, that is, agencies which are neither " art " nor "chance." Nothing in the universe is isolated and self-sufficient; everything depends upon innumerable external factors for its coming into being and for its very survival. It is to these receptivities for external influence that the idea of nature as a passive principle applies.

All such passive potentialities, obviously, must be actualized by external agencies. It is in this sense that Aristotle expressed the well-known axiom, that " whatever is moved is moved by something else." [61] When Aristotle discusses the causes of mo-

E" " Et propter hoc factiones rerum artificialium non sunt naturales: quia licet principium materiale sit in eo quod fit, non tamen habet poten- tiam naturalem ad talem formam." *Ibid.*

to " Differentia tamen est inter materiam naturalium et artificialium: quia in materia rerum naturalium eat [1] *aptitudo naturalis ad formam,* et [2] *potest reduci in actum per agens naturale;* non autem hoc contingit in materia artificialium." St. Thomas, *In VII Metaph., 8,* n. 1442z. (Italics mine.)

[01] The point is that this axiom applies only to nature as a *passive* prin-

tion in Book VIII of the *Physics,*™ he considers three classes of movement: living, compulsory, and spontaneous. The movement of living things is easy enough to explain, for living things move themselves, as we can see; therefore, they are the cause of their own motion (254bl4-24). Compulsory motion is also easily accounted for, since it is derived from the agent which imparts compulsion, for example, the hoy who throws the ball (254b24-33). But the greatest difficulty is presented in explaining the *cause* of spontaneous movement. " It is in these cases that difficulty would be experienced in deciding whence the motion is derived, e. g., in the case of light and heavy things" (255al-2). Obviously such bodies do not move themselves, that is, they cannot be the cause of their own motion, for this is the prerogative of living things (255a5-19). But Aristotle shows that although inanimate bodies spontaneously manifest their proper activities unless an obstacle intervenes, they first have to be generated *(moved)* from potentiality. For example, hydrogen exists potentially in water and must be generated by some agency before it can manifest the characteristic behavior of hydrogen. Thus inasmuch as each natural reality was at one time not yet actually existing, it had to be brought into actual being by an external agent. Aristotle's explanation depends upon his theory of intrinsic change: substantial natures

ciple. Sometimes this phrase is interpreted as " Everything that is in motion must be moved by something else," in the sense that every motion here and now requires a mover for the preservation of movement. (Ross' trans. of 241b24).. Sir David Ross, among many others, interprets Aristotle as meaning all motion requires actual contact with the mover for the duration of the motion; cf. *Aristotle's Physics* (Oxford 1936), comm, on 266al0-ll (pp. 721-22), 266b27-267a20 (pp. 725-26). Philosophically there is no need for a constant physical mover to account for motion; nor is this what Aristotle himself intends to say, as will be explained. We are not here discussing nature "inquantum agit in virtute Dei" *(Sum. cont. Gent.,* Ill, 66; cf. 67). That is a different question altogether. St. Thomas acknowledges that, " non est contra rationem naturae [i. e., ut principium activum] quod motus naturalis sit a Deo sicut a primo movente." *Summa Theol.,* I-II, 6, 1 ad 3. [sa] *Phys.,* VIII, c. 4, 254bl4-256a2.

are generated (moved) from pure potentiality into the full reality of a substance by an adequate agency. When such bodies are generated (moved), they must be moved by something else. But once such natures are actually existing, they spontaneously, *statim* (*euthus*), manifest their characteristic behavior unless externally impeded. However, every formal nature still has innumerable secondary receptivities whereby it depends upon and is woven into the whole fabric of the universe. Even these receptivities, by which every body is " open " to the universe, require external influence to achieve fulfillment.

Briefly, then, nature as a passive principle involves two factors. It essentially implies intentionality of ends, which are necessary for the good of the whole being. And it presupposes natural agencies which can actualize it.

II. Nature as Active Principle

In the proper and strict sense of the term, " nature " signifies an active principle of spontaneous behavior. It is a matter of experience that each physical reality in the universe steadfastly insists on being itself; it behaves in a characteristic way and, in a sense, refuses to behave in any other way. In other words, every physical reality manifests determined properties and behavior; and it is through such characteristics that different realities can be recognized. This is the very foundation of physical science. The human intellect, however, has no direct or *a priori* knowledge of " essences " or " natures "; it must carefully examine the sensible characteristics and behavior of natural bodies in various settings.[63] Since no physical unit operates in a void, but always in an actual environment, the qualitative characteristics of the actual environment must be taken into consideration when accounting for the various natural phenomena, for even the same reality will act differently in

[63] " Natura enim uniuscuiusque rei ex eius operatione oatenditur." St Thomas, *Summa Theol.,* I, 76, 1; cf. *Sum. cont. Gent.,* Ill, 69.

different environments. However, neither the environment, nor the proximity of sociable or unsociable factors should be confused with the actual spontaneity the body manifests under those circumstances. There is always the danger of thinking that we have found the explanation of a natural phenomenon when we have merely discovered a secondary factor. Apart from the natural receptivities each body has for external influence, there remains the fundamental spontaneity by which the body acts in its own right, acts as itself.

Aristotle's definition of nature as a *principle* must be understood in the strict sense of a relative term.[64] That is to say, " nature " is not some complete entity within physical bodies which springs forth now and then in its performance. *It neither is, nor can be known as a complete entity.* Our knowledge of it involves the experience of sensible manifestations and the realization that certain characteristic manifestations are spontaneously " given " in reality. Indeed, " natures " exist only in the concrete, existing individual, so that our knowledge of nature in general or any particular nature involves the actual experience of innumerable individual phenomena; and in no way can our " concept " of nature be separated from these personal experiences.[66] " Unde," St. Thomas says, " deridendi sunt qui volentes definitionem Aristotelis corrigere, naturam per aliquid absolutum definire conati sunt, dicentes quod natura est *vis insita rebus,* vel aliquid huiusmodi." [86] John Philoponus, considering Aristotle's definition to be rather a description *per*

[e4] " Ponitur autem in definitione naturae *principium,* quasi genus, et non aliquid absolutum, quia nomen naturae importat habitudinem prin- cipii." St. Thomas, *In II Phys.,* 1, n. 5.

[*s] " De ratione autem huius naturae est quod in aliquo individuo existat, quod non est absque materia corporali; sicut de ratione naturae lapidis est quod sit in hoc lapide, et de ratione equi est quod sit in hoc equo, et sic de aliis. Unde natura lapidis, vel cuiuscumque materialis rei, cognosci non potest complete et vere, nisi secundum quod cognoscitur ut in particular! existens." St. Thomas, *Summa Theol.,* I, 84, 7.

[«•] *In II Phys.,* 1, n. 5.

effectum, thought it should be corrected to " life or a force radicated in bodies, forming and directing itself." [67] St. Albert[68] and Roger Bacon [09] also defined nature as a *vis insita rebus.* In the latter half of the 15th century Basil Valentinus, a Benedictine alchemist, introduced an *archaeus* into the known alchemical elements by which the ruler of the universe determined the phenomena of chemical changes; other alchemists introduced a " celestial virtue." [70] Even at the time of J. B. van Helmont (1577-1644) the *archaeus* continued to be invoked as the seminal efficient cause which accounted for the figure, motion, and so forth of chemical elements.[71] Aristotelians of the 17th century referred to " nature " as a *virtue* or as an *occult specific quality.*[12] While it is true that "nature " is a kind of force, or

[7] Ioannis Philoponi, *In Arist. Physicorum liiros tres priores.* (Comm. Graeca, XVI) (Berlin, 1887) Lib. II, cap. 1, p. 197: 33-35.

[8] St. Albert: " Est enim natura vis insita rebus naturalibus ex similibus secundum naturam similia procreans." *In II Phys.,* tr. I, cap. 7 (ed. Borgnet, t. Ill, 103b) ; also cap. 5, p. 101a.

[60] Roger Bacon, *Quaestiones supra libros Quatuor Physicorum,* Lib. II, q. 7 *(Opera Hactenus inedita,* fasc. VIII, ed. Delorme, [Oxford, 1938], pp. 58-9; q. 8, pp. 59-00; *et passim.)*

[70] W.. C. Dampier, *A History of Science,* 4th ed. (Cambridge, Eng., 1949), p. 114. Dampier *(loc. cit.)* erroneously refers to Basil Valentinus as a Dominican monk. There can be little doubt that he was a Benedictine monk of Erfurt. Cf. Sudhoff in *Die Deutsche Literatur des Mittelalters: Verfasserlexikon,* Bd. I (Berlin, 1933), pp. 176-7; Herman Kopp, *Die Alchemie in alterer und neuerer Zeit* (Heidelberg, 1882). The oldest known Ms. of Valentinus (Oxford, Ash. 1447) refers to him as " monachi Ger- mani," which would not be accurate if he were a Dominican Friar. Cf. *Catalogue of the Ashmolean Manuscripts,* 1447 (IX, 3) : " Medicina catho- lica Basilii Valentini monachi Germani, chymiatri summi, ab ipso lapis ignis vocata cum quibusdam aliis medicinis et experimentis."

[71] Cf. A. Crombie, *Augustine to Galileo* (London 1952), pp. 355-7. "The seminal efficient cause archaeus containeth the Types or Patterns of things to be done by itself, the figure, motion, houre, respects, inclinations, fitnesses, equalizings, proportions, alienation, defect, and whatsoever falls under the succession of dayes, as well as in the business of generation, as of government." J. B. van Helmont, *Oriatrike,* chap. 4, quoted by Dr. Crombie, *op. cit.,* p.. 356.

[73]Cf. I. Newton, *Opticks* (London, 1704), pp. 375-8; R. Boyle, *A Free inquiry into the received 'Notion of Nature, Works* (London, 1744), IV, 358-424.

power, this way of speaking too easily conveys the idea of a little imp contained within bodies, which accounts for the various phenomena. In a precise analysis of meaning it is more accurate to say that our concept of nature is a reflexive realization that certain phenomena are spontaneously " given " as from the body itself.

Prof. Collingwood describes Aristotle's nature as a world of self-moving, living things.[73] But this is to confuse the spontaneity of nature with the prerogative of living bodies. Aristotle himself was careful to point out the essential difference between living and non-living things.[74] The fundamental attribute of living things is that they *move themselves,* that is, they themselves are the *cause* of their own motion. The soul of living things is the sufficient mover, the *causa efficiens,* of such activities as flying, walking, swimming, digestion, reproduction, and growth. But there are other characteristics of each and every living body of which the soul is not the " mover," but merely the spontaneous source, for example, the color and size of the creature,[75] its position on the earth and its falling down,[70] the chemical processes of metabolism, and the throbbing of life itself.[77] In other words, when discussing the characteristics of living things, two aspects must be carefully distinguished: i) those characteristics which arise spontaneously from the very existence of the being, given the necessary environment; ii) those phenomena which are actively caused by it. Nature as an active principle is not the " mover," or the " efficient cause " of natural phenomena, but only the " given " spontaneous source which was begotten by some effective agency.

For St. Thomas the " formal principle " of every physical being is truly an *active principle* of characteristic behavior, but

*• R. Collingwood, *Idea of Nature, op. cit.,* pp. 82-85.
T‹ Cf. Arist., *Phys.,* VIII, c. 4; *De Anima* I, c. 3, 5, etc.
" St. Thomas, *In II De Anima,* 8, n. 332.
St. Thomas, *In VIII Phys.,* 7, n. 3.
.TSt. Thomas. *In De Motu Cordis,* n. 7-8, *Opuscula Omnia* (Paris, 1949), t. I, 67-68.

not the *motor* or *principium motivum*. The reason for this is obvious. If the essential characteristics of a living thing is *to move itself,* then self-movement cannot be the property of a non-living thing. That is, an inanimate being cannot be the cause of its own activity. In a very technical sense, the " efficient cause" (if one raises the question) of spontaneous phenomena is the agency which brought such a being into existence. In other words, whatever agency produces a physical body must also be acknowledged as the agency responsible for all the inseparable and spontaneous characteristics of that body. But physical bodies not only exist, they also manifest activity and movement. Therefore, St. TJ imas very frequently insists that " in heavy and light bodies i~.;ure is a formal principle of movement, for just as the other attributes follow upon substantial form, so too does place, and consequently motion toward place; not that the natural form is a mover, but the mover is the progenitor which produced such a form, upon which such motion follows." [78]

[78] In *II Phys.,* 1, n. 4 (text below) ; cf. *In I De Coelo,* 18, n. 1; II, 2, n. 6; III, 7, nn. 5-9; *In II Phys.,* 5, n. 5; IV, 12, n. 9; VIII, 8, nn. 5-7; *Bum. cont. Qent.,* Ill, 82, 84; *De Pot.,* V, a. 5.

The text of *In II Phys.,* 1. 1, n. 4 is given in all printed editions, including the Leonine, a9 follows:

" In corporibus vero gravibus et levibus est principium formale sui motus *(sed huiusmodi principium formale non potest did potentia activa, ad quam pertinet motus iste, sed comprehenditur sub potentia passiva: gravitas enim in terra non est principium ut moveat, sed magis ut moveatur)* : quia sicut alia accidentia consequuntur formam substantialem, ita et locus, et per consequens moveri ad locum: non tamen ita quod forma naturalis sit motor, sed motor est generans, quod dat talem formam, ad quam talis motus consequitur."

At first sight the phrase in parentheses seems to contradict the doctrine expounded in the text. The phrase in question actually disrupts the smooth flow of thought in St. Thomas' reasoning. The Leonine editors admit that the text in question is not to be found in any of the codices: " Haec omnia, quae parenthesi clausimus omittuntur a codicibus. Et revera non videntur necessario postulari a contextu, et iis omissis, ratio quae immediate ponitur, *quia sicut alia,* melius cohaeret cum praecedentibus, ad quae referri debet, nempe *In corporibus vero,* etc." (*Opera Omnia,* ed. Leonine, t. II, p. 56a, note a). This passage is really taken from St. Thomas' *Commentary on*

From this it is clear that Aristotle did not explain natural motion by the constant exerted efficiency of a mover, as is often thought.[79] Aristotle insists that " it is not the action of another body that makes one of these bodies move up and the other down; nor is it constraint, like the ' extrusion ' of some writers." [80] Commenting on this passage St. Thomas says there

the Metaphysics, 14 (n. 955), probably in answer to Scotus' position (cf. Venice ed. of St. Thomas' commentary, 1595, fol. 31a). In this passage St. Thomas is discussing the different senses of *potestas.* The first sense expresses a " principium motus et mutationis in alio inquantum est aliud," that is, an *efficient cause.* (Cf. also *In IX Met.,* 7). In Aristotelian terminology an efficient cause is frequently called *potentia activa;* as has been explained, " nature " is not an efficient cause, although it is an *active* and *formal principle.* A careful reading of the collated text of this passage of the *Commentary on the Metaphysics* will show the precise point St.. Thomas has in mind:

> "Est enim quoddam principium motus vel mutationis in eo quod muta- tur, ipsa scilicet materia vel aliquod principium formale, ad quod consequitur motus, sicut ad formam gravis vel levis sequitur motus sursum aut deorsum. Sed huiusmodi principium non potest dici potentia activa, ad quam pertinet motus iste. Omne enim quod movetur ab alio movetur. Neque aliquid movet seipsum nisi per partes, inquantum una pars eius movet aliam, ut probatur in 8 Phys. Natura igitur, secundum quod est principium motus in eo in quo est, non comprehenditur sub potentia activa, sed magis sub passiva. Gravitas enim in terra non est principium ut moveat, sed magis ut moveatur. Potentia igitur activa motus oportet quod sit in alio ab eo quod movetur, sicut aedificativa potestas non est in aedificato, sed magis in aedificante."

The meaning of the passage, then is that nature as a formal principle is not a *potentia activa* or *effectiva.* Therefore even the phrase inserted in the parentheses above does not contradict our exposition, for nature as a formal, or active principle is not an efficient cause..

The above text of the *Commentary on the Metaphysics* has been collated with the following MSS.: Brit. Museum, Add. 18,375; Vat. lat. 767;
\ at. lat. 768; Vat. lat. 769; Vat. Pal. lat. 1063; and Ms.. Leonina (s. xiv). Sincere gratitude is due to Father A. Dondaine, 0. P., for valuable aid in checking this passage as well as others in the course of our study.

[7]" P- Hoenen, *Cosmologia,* 4a ed. (Rome, 1949), p. 494; Liberatore, *Institutions Philosophicae, Cosmologia,* n. 99 (Prati, 1881), p. 95; H. Butterfield, *The Origins of Modern Science* (London, 1951), pp. 3-4; W. C. Dampier, *op. cit.,* p. 131; A. C. Crombie, *Augustine to Galileo* (London, 1952), p. 82.

[80] Arist., *De Coelo,* I, c. 8, 277bl-2; the reference is to the Atomists,
Leucippus and Demoe-itus, who postulate the Vortex *(dine)* to account for motion.

are some who postulate a *per se* mover to account for the movement of bodies even after such bodies already exist; this Aristotle is denying, for light bodies are moved upward and heavy bodies downward by the progenitor inasmuch as it produced that type of body in the first place.[81] In a secondary sense whatever deflects the normal path of motion or whatever removes an obstacle to spontaneous movement can also be called an accidental cause of the movement.[82] The important point is that once a particular body is in existence, there is *no need* for an agent constantly acting upon it to account for its activity. The body itself *acts.*

Nor can the " form " be said to be the " mover accompanying the bodies which it moves." [83] For Aristotle as well as for St. Thomas the form is *not the mover,* but the *source* of necessary and spontaneous movement. Avicenna in his *Sufficientia* [81] and

*[1] " Per quod quidem intelligendum est quod removet exteriorem motorem, qui per se huiusmodi corpora moveat postquam sunt formam specificam sortita. Moventur enim levia quidem sursum, gravia autem deorsum a generante quidem, inquantum dat eis formam quam consequitur talis motus; sed removente prohibens, per accidens et non per se. *Quidam vero posuerunt quod postquam speciem sunt adepta huiusmodi corpora indigent ab aliquo extrinseco moveri per se: quod hio Philosophus removet" In I De Coelo,* 18, n. 1 (italics mine).

•* Cf. *In VIII Phys.,* 8, n. 7: " sicut si sphaera, idest pila, repercutiatur a pariete, per accidens quidem mota est a pariete, non autem per se; sed a primo proiiciente per se mota est. Paries enim non dedit ei aliquem im- petum ad motum, sed proiiciens: per accidens autem fuit, quod dum a pariete impediretur ne secundum impetum ferretur, eodem impetu manente, in contrarium motum resilivit. Et similiter ille qui divellit columnam, non dat gravi superposito impetum vel inclinatonem ad hoc quod sit deorsum: hoc enim habuit a primo generante, quod dedit ei formam quam sequitur talis inclinatio. Sic igitur generans est per se movens gravia et levia, removens autem prohibens per accidens."

>! Hoenen, *Cosmologia, op. cit.,* pp. 497-502; Crombie, *Augustine to Galileo, op. cit.,* p. 82.

•* Cf. H. A. Wolfson, *Crescas' Critique of Aristotle* (text, trans. and commentary) (Cambridge, 1929), pp. 672-5; also Carra de Vaux, *Avicenne,* pp. 184-5. The late 14th century Jewish philosopher, Crescas, also follows the Arabian tradition, cf. *Critique (Or Adonai)*, ed. Wolfson, prop. XVII, pp. 296-9.

Algazel's paraphrase, *Maqacid el-falacifa,*[BS] propound the theory that in natural movement the form is the mover of the body which it informs. In a certain sense Averroes too follows this opinion.[86] But the Aristotelian answer to this theory is obvious: if the natural form moves the body which it informs, then what is the difference between living and non-living things? For Aristotle and St. Thomas no such distinction can be drawn in non-living things between form as mover and body as moved, for each non-living thing is a single continuous whole, without parts; only by part moving part can the living organism exercise self-motion.[87]

Thus nature as an active principle differs both from life and from pure inertia; it partakes of the activity of living things inasmuch as natural bodies have within themselves an active source of spontaneous activity, and it partakes of the passivity of potentiality inasmuch as such activity is the result of having been brought into existence by some external agency. Because natural spontaneity is not to be confused with life, St. Thomas sometimes refers to nature as a *principium passivum.*[8]* But in every one of these passages St. Thomas is merely insisting that this principle (nature) should not be considered as a *principium motivum* (*efficiens*), or *causa se movens.*

•* *Algazel's Metaphysics,* ed, J. T. Muckle (Toronto, 1933), pp. 30-31; 99-102. Concerning the nature of the *Maq&cid,* cf. D. Salman, " Algazel et les Latins" in *Arch, d'hist. doctr. et litt. du M. A.,* X (1935), 103-127.

[8]" Averroes, Phys., VIII, c. 4, comm. 29-32; theory proposed and refuted by St. Thomas, *In III De Coelo,* 7, nn. 8-9. See also Ernest A. Moody, "Galileo and Avempace," in *Journal of the History of Ideas,* XII (1951), 163-193, 375-422.

[T] Cf. Arist., Phys., VIII, c. 4, 255a5-19; St. Thomas, *In Till Phys.,* 7, nn. 6-8; *In VII Phys.,* 1, n. 2. The basic error of Avicenna is his conception of form as a *thing* in its own right, cf. St. Thomas, *Summa Theol.,* I, q.
110, a. 2; *Sum. cont. Gent.* Ill, c. 68; also P. Hoenen, *De Origine Formae Materialis* (Rome, 1932). In animate activity the whole subsistent being is responsible for the subsequent movement, which it accomplishes through the various organic parts. Since inanimate things have no organic parts, they cannot move themselves.

St. Thomas, *In VIII Phys.,* 8, n. 7; *In I De Coelo,* 3, n. 4; II, 2, n. 6; 3, n. 2; III, 7, nn. 8-9.

The linguistic inadequacies of expressing both the natural spontaneity of physical bodies and the obvious fact that they are not living produced considerable confusion among later scholastics. Duns Scotus, following Avicenna, describes nature as an active principle which in a sense moves itself to activity.[89] Dominic de Soto (1494-1560) insists that in no sense can nature be called an " active principle " for this is the prerogative of living things.[90] By the 17th century John of St. Thomas (1589-1644) could refer to the " celebrated difficulty," whether natural bodies are moved by an intrinsic active or passive principle.[91] But the difficulty was more verbal than real. Even Dominic de Soto proposed the now common distinction among Thomists, that the nature of inanimate things is a *principium " quo "* of their activities, while the cause of the nature is the *principium " quod."*[92]

Nature is not only a source of activity, but also of rest *(eremein)* ,[93] This should not be understood as the mere absence of activity, but as the positive possession of fulfillment. In

" Joannis Scoti, *Comm, in II Sent.,* d. 2, q. 10.

[60] Dominici de Soto, *Super Octo Physicorum Quaestiones,* 2a ed., Salman- tice, 1551, super II, q. 1, fol. 31v-34r; cf. super VIII, q. 3, fol. 104r-v.

[91] Joannis a S. Thoma, *Cursus Philosophicus,* Phil. Nat., I P., q. IX, a. 2, ed. Reiser (Rome, 1933), t. II, p. 184b; q.. 23, a. 1, p. 461a.

" Mens igitur Aristotelis est quod principium naturalis motus elemen- torurn est duplex: aliud *quo,* et aliud *quod-,* principium *quo* principale est forma ipsa substantial is; minus autem principale et instrumental, est gravitas et levitas; principium autem *quod* est generans." Soto, *Quaest. super Till Phys.,* q. 3. *ed. cit.,* fol. 104r, col. 2; cf. J. a S. Thoma, *op. cit.,* q. 23, a. 1 ad 3; *ed. cit.,* p. 458a; C. Alamano, *Summa Philosophiae,* P. II, q. 34, a. 2 ad 4 (Paris, 1890).

[93] Arist., *Phys.,* II, c. 1, 192b20. Some of the ancient commentators, notably Alexander and Porphyry (according to Simplicius, *Commentaria in Arist. de Physico,* [Venetiis, 1546] Lib. II, fol. 42v-43r), Simplicius himself *{ibid.),* and Philoponus *(In Physica,* ed. Vitelli, [Berlin, 1887] t. XVI, 198- 199) were more or less embarrassed with this part of Aristotle's definition, since there is no rest to celestial motions. But St. Thomas points out that Aristotle only wishes to say that " nature " is responsible for rest as well as for activity in those bodies which naturally come to rest. Cf. *In II Phys.,* 1, n. 5.

other words, all movement essentially implies the attainment of something; it necessarily implies some kind of aim to be attained.[94] This is not to say that absolute *rest* exists in the universe. Constant movement is an evident phenomenon of experience. But to every particular movement there corresponds some finality attained, even if it is only the self-preservation of the individual. Strictly speaking, movement for its own sake is inconceivable, for the very reality of movement consists in some " otherness " to be attained, some achievement through activity. Therefore " nature " cannot be the source of mere activity, but it must primarily aim at some achievement acquired through movement. In other words, just as all movement implies some "aim," the spontaneous source of movement necessarily has some aim in view.[05] As we shall see, it was this consideration which led the ancients to postulate celestial movers for the heavenly bodies which move locally without attaining any internal finality. The " rest " of which Aristotle speaks must be taken in the wide sense of the possession of fulfillment, whether of characteristic attributes or of internal finality acquired through activity. This internal finality and fulfillment may be described aptly by Whitehead's expression as "self-enjoyment."

•* If there were no aim whatever, the body could not move at all, for the aim is the reason for the movement. Since motion is not an end in itself, St. Thomas insists that " natura nunquam inclinat ad motum propter movere, sed propter aliquid determinatum quod ex motu consequitur." *De Pot., V, 5;* cf. *Sum cont. Gent.,* Ill, 23.

This is not to say that inanimate beings have consciousness or knowledge of their aim. While it is true that such terms as " aim," " desire," " appetite," " intentionality," etc. are primarily used in the context of human activity, the *analogical* use of these terms with regard to inanimate movement does not mean to imply consciousness of aim in the bodies themselves. However, this aim does imply a Supreme Intelligence which directs natural things. " Tendunt enim in finem sicut directa in finem a substantia intelligente, per modum quo sagitta tendit ad signum directa a sagittante." (St. Thomas, *Sum cont. Gent.,* Ill, 24). The scholastic terminology was commonly attacked in the 17th century by such men as Bacon, Boyle, etc. as the expression of animism and anthropomorphism; this was due to a misconception of *analogical usage—a* human necessity.

The Aristotelian conception of active nature is remarkably similar to Whitehead's description of nature as " life." [80] Whitehead is fully aware of the essential difference between animate and inanimate reality. However, he sees such a vast similarity that he considers the notion of " life," in the wide sense of the term, as the key to understanding the whole of reality. Against a background of a temporal advance and essential inter-connectedness of physical reality each unit manifests a similarity to organic life. This analogy consists in three aspects, which Whitehead terms " creative activity," " aim," and " self-enjoyment." [97] By creative activity is meant the spontaneous and novel production of an event, so that every being, in a sense, creates from within its own structure and activity. " It is the clutch at vivid immediacy " and the principle of novelty.[98] By " aim " Whitehead means " the exclusion of the boundless wealth of alternative potentiality, and the inclusion of that definite factor of novelty which constitutes the selected way of entertaining those data in that process of unification." [99] That is, every body intrinsically aims at a particular way of enjoyment, utilizing the environment for its proper fulfillment. Finally, " self-enjoyment " is the organic unity and self-identity of the individual " arising out of this process of appropriation." [100] Whitehead strongly objects to the lifeless and inert character of the Newtonian-Humean universe. He insists that " nature is full-blooded; real facts are happening." [101] Thus Whitehead has reintroduced into philosophy spontaneous activity and finality, the two essential elements in the Aristotelian conception of nature.

[86] Cf. *Modes of Thought,* Part III, " Nature and Life," pp. 173-232.

[87] *Ibid.,* p. 208.

[88] *Process and Reality,* p. 160.

[88] *Modes of Thought,* pp. 207-8.

[100] *Ibid.,* pp. 205-6.

[101] *Modes of Thought,* p. 197; see also pp. 173-201, and his *Science and the Modern World* (Cambridge, 1946), pp. 49-141.

Nature, then, as an active principle involves two essential factors. It is essentially a source of spontaneous activity and characteristics; conceptually it is the reflexive realization that certain characteristic manifestations of every physical body are spontaneously " given " in reality. And this implies an intrinsic finality, or aim, which is the fulfillment and " self-enjoyment " of the individual. Just as intentionality of purpose and passivity characterize the idea of nature as a passive principle, so intentionality and intrinsic spontaneity characterize the idea of nature as an active principle.

CHAPTER III

Natural and Compulsory Movement

THE CONCEPT of nature which has been expounded[1] necessarily implies a selection or determination of activities which are conducive to the well-being of the individual. Nature as an active principle is a spontaneous source of purposeful activities, determined characteristics which are for the fulfillment of the individual. Thus carbon does not act in the same way as, let us say, helium. Likewise the " natural " receptivities of any physical being are only those which are conducive to the well-being of the whole, as was explained. Thus if nature both as an active and as a passive principle has a determined " aim," that is, intrinsic intentionality of purpose, there necessarily follows a distinction between those activities within the ambit of intentionality and those which are not. That is to say, there necessarily follows a distinction between " natural " and non-natural activity. In this sense, " natural " activity would be any characteristic behavior spontaneously produced by the body in a particular environment, or at least one for which the body has a connatural receptivity in its favor. Conversely, non-natural activity would be all movements which are foisted upon it from without. These non-natural movements may be the result of chance, human control, or violent force. The essential characteristic of non-natural or compulsory movement is that there is no intrinsic intentionality of that activity on the part of the being itself.

Whenever the notion of " aim " is introduced, such a distinction between natural and non-natural activity necessarily follows. Thus, although A. N. Whitehead attacks the Aristotelian

[1] J. Weisheipl, " The Concept of Nature," in THE NEW SCHOLASTICISM XXVIII (1954), 377-408.

distinction as an unfortunate and hasty classification,[2] his own principles of philosophy demand this distinction. Whitehead maintains the essential self-identity of each individual reality in the universe and the self-identity of different types. He insists that each unit of reality, which spontaneously creates its activity, *aims* at producing its own individual and typical " self-enjoyment." By *aim* Whitehead explicitly acknowledges " the exclusion of the boundless wealth of alternative potentiality, and the inclusion of that definite factor of novelty which constitutes the selected way of entertaining those data in that process of unification." [3] That including of definite factors in the process of unification is what Aristotle calls " natural movement." Those potentialities which are intrinsically excluded, but which results from an external intrusion, are called nonnatural by Aristotle.

This distinction between natural and non-natural movement would have no meaning in a world of complete inertia, that is, in a world where intrinsic intentionality of purpose is excluded —really or philosophically. The relevance of this distinction lies properly in the order of final causality. When final causality is denied, the distinction ceases to have any meaning.

Pierre Duhem's monumental studies on the precursors of Galileo are designed to prove a thesis which has subsequently found favor among many historians of modern science. Duhem maintains that it was the overthrow of the Aristotelian distinction between natural and compulsory movement by means of the theory of impetus which led to the principle of inertia, the corner-stone of modern physics.[4] Anneliese Maier, however,

[3] " The greatest curse to the progress of science is a hasty classification based on trivialities. An example of what I mean is Aristotle's classification of motions into violent and natural." A. Whitehead, *Essays in Science and Philosophy* (London, 1948), pp. 174-5.

[3] A. Whitehead, *Modes of Thought* (Cambridge, Eng., 1938), pp. 207-8.

'P. Duhem, *etudes sur Leonard de Vinci*, 3 vols. (Paris, 1906, 1909, 1913); *Systeme du Monde,* 5 vols. (Paris, 1913-17); "Physics—History of," *Catholic Encyclopedia* (New York, 1911), XII, 47-67. Cf. also R. Dugas,

maintains that Duhem has exaggerated the role of impetus and has partly misrepresented the historical problem.[5] In fact, Maier maintains that the theory of impetus is a natural development of Aristotelian doctrine, and that this theory is very different from the principle of inertia proposed in the 17th century.[6] Without delving into this vast subject, it is important to consider briefly the theory of impetus and the principle of inertia in order to see more clearly the significance of "natural" motion.

I. The Theory of Impetus

The problem of explaining the movement of projectiles and every "non-natural" motion inevitably arises in an attempt to maintain the reality of nature as a source of determined behavior. The difficulty is to explain the continuation of such motion after it has left the source of projection. If the upward movement of a stone is not due to the stone itself but to the hand which threw it, what is responsible for the continued movement after it has left the hand? The principle of sufficient reason demands that *something* be responsible. It is obvious that the

Histoire de la Micanique (Neuchatel, 1950), pp. 19-104; H. Butterfield, *The Origins of Modern Science* (London, 1951), pp. 1-14; P. Hoenen, *Cosmologia,* 4th ed. (Rome, 1949), pp. 482-508; E. Whittaker, *A History of the Theories of Aether and Electricity* (London, 1951), I, 1-6; R. Masi, " Nota sulla storia del principio d'inerzia," in *Rivista di Filosofia Neo- scolastica,* XL (1948), 121 ff.

[6] "Duhem hat in grossangelegten Untersuchungen, die freilich der Nach- priifung im einzelnen nicht immer standhalten, den Ursprung der Ge- schichte der Theorie verfolgt, und das Verdienst, als erster auf sie hinge- wiesen und sie herausgestellt zu haben, wird ihm immer bleiben. Aber in der Beurteilung ihrer Bedeutung ist er, wenn nicht zu einer uberschatzung, so doch mindestens zu einer falschen Einschatzung gekommen. Die scho- lastische Naturphilosophie stellt im Vergleich zu der physikalischen Vor- stellung der Neuzeit eine so heterogene Gedankenwelt dar, dass wir sie nur von ihren eigenen Voraussetzungen aus begreifen konnen." *Zwei Orund-probleme,* II Abschnitt: *Die Impetustheorie,* 2nd ed. (Rome, 1951), pp. 113-4.

[8] A. Maier, *op. cit.,* pp. 113-4; cf. *Die Vorldufer Oalileis im Ilf. Jahr- hundert* (Rome, 1949).

stone does not move itself upward, for this is a property of living things only. The stone does not move upward spontaneously, for this movement is contrary to its " nature." The hand which threw it does not continue the movement, for the stone is no longer in contact with the hand. Since something must be responsible for the continuation and none of these possibilities are admissible, the problem arises of finding the explanation.

Aristotle himself saw the difficulty, but his solution, which is subject to some misunderstanding, was later found to be erroneous. However, it is important not only to know precisely what Aristotle maintained, but also *why* he maintained it, for in this lies the validity of Aristotle's position.

Aristotle considers the problem in three brief passages; [7] and in all of these passages his insistence is that not even violent movement can take place unless the natural is presupposed. In Book VIII of the *Physics* Aristotle proposes the problem and suggests two solutions: that of Plato and his own. For Plato bodies have only one proper movement, namely motion to their proper place in the Receptacle. Even this movement is explained by the shape of the elementary bodies and the shaking of the Receptacle by the Soul.[8] All other movements take place by collision and mutual replacement, *avTLTrepicrTacrLs,* that is, the air or water pushed in front of the projectile gathers in behind it and so pushes it on.[9] Aristotle objects that in this explanation

[7] Arist., *Phys., IV,* c. 8, 215al-18; VIII, c. 10, 266b27-267a22; *De Coelo,* III, c. 2, 301bl7-33.

[8] Cf. Plato, Timaeus, 49 A-53 A; 57 B-58 C. See also P. Cornford, *Plato's Cosmology* (London, 1937).

[9] " And, indeed, with respect to all the motions of water, the falling of thunder, and the wonderful circumstances observed in the attraction of amber, and the Herculean stone,—in all these, no real attraction takes place at all; but as a vacuum can nowhere be found, the particles are mutually impelled by each other; hence, as they all individually, both in a separate and mingled state, have an attraction for their own proper place, it is by the mutual intermingling of these affections, that such admirable effects present themselves to the view of the accurate investigator." Plato, *Timaeus,* 80 C; cf. 59 A, 79 B, C, E.

only motion itself is conferred by the mover, in which case " all the things moved would have to be in motion simultaneously and also to have ceased simultaneously." [10] He insists that the only way to explain the continuation of movement in the projectile is to say that the mover gives not only motion but also a power of moving (δύναμις τοῦ κινεῖν ἐγγίγνεται) to the " air or to water or to something else of the kind, naturally adapted for imparting and undergoing motion." [11] Movement is thus retarded when the motive force imparted decreases until finally " one part of the medium no longer causes the next to be a mover but only causes it to be in motion." [12]

In Book III of the *De Coelo* Aristotle shows why this power of moving must be given to the medium. Since projectile motion is " violent " and violence implies " a source of movement in something other than itself or in it *qua* other," [13] the source of such motion cannot be in the body itself. To attribute this motive force to the body would be to give it an internal principle, while violence is always from without. Furthermore, that external source of violent motion must be naturally adapted to producing the motion, otherwise the same problem arises as with the projectile itself. But air and water, according to Aristotle's doctrine, are naturally both " heavy and light," depending upon the actual environment. Thus the motive power can be given to the medium; the air " *qua* light produces upward motion, being propelled and set in motion by the force."[14] Therefore, in Aristotle's view, the upward movement of the projectile is possible, because the medium is naturally endowed with this function of upward and downward motion; and he insists that "if the air were not endowed with this function, constrained movement would be impossible." [15]

[10] Arist., *Phys.* 266b34-267a2.
[xl] *Ibid.,* 267a4-5; see 267a8-9.
[12] *Ibid.,* 267a9-10.
[13] *De Coelo,* III, c. 2, 301M8-19.
[14] *Ibid.,* 301b24-25.
[1E] *Ibid.,* 301b29-30.

This same idea lies behind the passage in Book IV of the *Physics*.[16] He argues against the existence of a void by insisting that violent motion cannot arise from a source internal to the projectile, but must be caused by an external medium. Since in a void there is no medium, Aristotle concludes that even violent motion would be impossible if actual space were a void.

The important point to notice is that Aristotle appeals to air to explain projectile motion, not because all movement must be *ab alio,* but because such movement is "violent," and *therefore* must be from an extrinsic source. Aristotle defines violent movement as " that whose moving principle is outside, the thing compelled contributing nothing." [17] This is the fundamental reason for appealing to an external source, such as the air. It is this idea of an "extrinsic," "non-natural " source which lies behind the scholastic development of impetus.

The Christian scholar, John Philoponus of Alexandria (6th century), seems to have been the first to show that the medium cannot be the cause of projectile motion.[18] If it is really the air which carries the stone or the arrow along, as Aristotle claims, then why must the hand touch the stone at all, or why must the arrow be fitted to the bow string? One can beat the air violently and still not move the stone. Furthermore, a heavier stone can be thrown farther than a very light one, but if air is the cause of this motion, a very light stone should obviously travel farther. Then, too, why is motion deflected when two bodies collide and not when they merely pass each other? In fact, Philoponus points out, the air—and every medium—offers resistance to motion, so that instead of being a cause, it is rather an obstacle. Therefore, he concludes that violent motion cannot be explained by the Aristotelian theory. "On the con-

™*Phys.,* IV, c. 8, 215al3-18.

[17] Arist., *Eth. Nic.,* Ill, c. 1, lllOblo; cf. 1110a2; *De Coelo,* III, c. 2, 301bl8-19.

[13] Ioannis Philoponi, *In Arist. Physicorum libros quinque posteriores commentaria,* ed. Vitelli, *Commentaria Graeca,* XVII (Berlin, 1888), Lib.
IV, cap. 8, pp. 336-642,

trary, it is necessary that a certain incorporeal motive power (κινητικήν τινὰ δύναμιν ἀσώματον) be given to the projectile through the act of throwing." In other words, Philoponus insists that it is not to the medium that the thrower gives the motive power but to the projectile itself. This, Duhem says, is the language of " common sense." [19] However, Philoponus points out that this motive " energy " (ἐνέργεια) is only borrowed and is decreased by the natural tendencies of the body and the resistance of the medium.

Unfortunately, Simplicius (d. 549) did not bother to present Philoponus' position clearly, but in two of his " Digressiones contra Ioannem Grammaticum," [20] he attacks the denial of what he thinks to be the fundamental principle involved, namely, the denial of " whatever is moved must be moved by something else in contact with it." He himself develops a peculiar theory whereby the projectile and the medium alternately act upon one another until the *vis motrix* is exhausted. He confesses that he is insisting upon this for two reasons: whatever is moved must be moved by something else, and the two must be in contact.[21] Medieval knowledge of Philoponus was largely limited to the report of Simplicius.

It is not clear what influence, if any, Philoponus' theory had on the formation of the scholastic notion of impetus. Duhem believes that it came through the *Theorica Planetarum* of the Spanish-Arabian astronomer, Alpetragius (A1 Bitruji),[22] which work was translated into Latin by Michael Scot in 1217.[23]

[18] P. Duhem, *Le Systeme du Monde,* I, 383.

[20] After VIII *Phys.,* comm. 8 and comm. 12, Simplicii *Commentaria in octo Libros Physicorum* (Venice, 1546), 2a pars, fol. 51v-54v; fol. 57v-59r.

[21] *Ibid.,* fol. 91r a.

[22] Duhem, *fitudes sur Leonard de Vinci,* II, 191 ff.; Ill, 23; also R. Dugas, *Eistoire de la M4canique,* ed. cit., p. 47. The title, *Theorica Planetarum,* was given to this work by Calonymos ben David whose translation from the Hebrew was printed in Venice in 1531, fol. 277-303. Today the work is more correctly known as *De Motibus Celorum.*

[23] Cf. C. Haskins, *Studies in the History of Mediaeval Science,* 2nd ed. (Cambridge. .Mass., 1027), pp. 272-298. A critical edition of the Latin

But Maier has shown that Duhem quotes from the printed edition of 1531 in which the theory of Philoponus is very clear, but the Scot translation of the pertinent passage has no connotation whatever of an impetus theory.[24] Pines, discussing the Arabic theories of impetus, suggests that it may have been through Avicenna's commentary on the *Physics.*[25] But the Latin version, known as the *Sufficientia,* contained only the first four books, and the single vague reference in Book II, chapter 8, can be understood in an Aristotelian sense.[26] Maier believes that the scholastics developed the theory independently, mainly through their discussions of instrumental causality in the sacraments and reproduction.[27]

Although the Aristotelian theory was generally accepted in the thirteenth century, the reason for accepting it is clear: violent motion cannot be accounted for by an internal, innate source.[28] St. Thomas, discussing reproduction, points out the essential difference between natural and non-natural motive forces: " virtus quae est in semine a patre, est *virtus permanens ab intrinseco, non influens ab extrinseco,* sicut virtus moventis quae est in proiectis."[20] Since violent motion is always alien

translation of Michael Scot has been edited by F. Carmody, *De Motibus Celorum* (Berkeley, 1952).

[24] A. Maier, *Zwei Grundprobleme,* pp. 127-129. See Scot's trans. VIII, 11, ed. Carmody, p. 93.

[25] S. Pines, " Les precurseurs musulmans de la th^orie de l'impetus," *Archeion* XXI (1938), 298 ff.

[20] Cf. A. Maier, *Zwei Grundprobleme,* pp. 129-133.

[21] *Ibid.,* pp. 133-34.

[28] Cf. St. Albert, *In Phys.,* VIII, tr. IV, cap. 4; *In Phys.,* IV, tr. II, cap. 5; *In De Coelo,* III, tr. I, cap. 7; St. Bonaventure, II *Sent.,* dist. 31, a. 1, q. 1; Roger Bacon, *Quaestiones super libros Physicorum,* Lib. VII, ed. Delorme (*Opera hactenus inedita,* fasc. XIII [Oxford, 1935]), pp. 338-347. "Non est autem intelligendum quod virtus violenti motoris imprimat lapidi qui per violentiam movetur, aliquam virtutem per quam moveatur, sicut virtus generantis imprimit genito formam, quam conse- quitur motus naturalis: *nam sic motus violentus esset a principio intrinseco, quod est contra rationem motus violenti."* St. Thomas, *In III I>e Coelo,* lect. 7, n. G (emphasis mine).

[29] *De Anima,* 11 ad 2.

and borrowed, it lasts only as long as the force remains, being resisted by the natural forces of the body.[30]

The scholastic theory of impetus seems to have been first suggested by the Franciscan, Franciscus de Marchia. While discussing sacramental causality, he raises the question of impetus, in order to show that both the sacraments and the projectile have a certain force resident within by which something is produced.[31] After a long and careful discussion of the Aristotelian theory, he concludes that projectile motion cannot be explained by the air, but must be explained by a *virtus derelicta in lapide a motore*.[32] However, he is careful to point out that this force is not permanent or innate; it is rather an " accidental and extrinsic force," a " certain extrinsic form." [83] Therefore, this accidental force is alien and repugnant to the natural inclination of the body; it is, indeed, a "violent" and nonnatural source of movement.[34]

[80] " Instrumentum intelligitur moveri a principali agente, quamdiu retinet virtutem a principali agente impressam; unde sagitta tamdiu movetur a proiciente, quamdiu manet vis impulsus proicientis." St. Thomas, *De Pot.,* Ill, 11 ad 5; cf. *Sum. cont. Gent.,* Ill, c. 24: " Sicut enim sagitta consequitur inclinationem ad finem determinatum ex impulsione sagittantis, ita corpora naturalia consequuntur inclinationem in fines na- turales ex moventibus naturalibus, ex quibus sortiuntur suas formas et virtutes et motus." A. Rozwadowski, basing himself on the last three cited texts *(De Anima,* 11 ad 2; *De Pot.,* Ill, 11 ad 5; *Sum. con. Gent.,* Ill, c. 24), tries to show that St. Thomas held the theory of impetus in the same sense in which it was later expounded by Jean Buridan and his school. Cf. " De motus localis causa proxima secundum principia S. Thomae," *Divus Thomas* (Piacenza), XLII (1939) 104-113. Duhem thinks that in these passages St. Thomas is using a popularly expressed similarity. Father M.-D. Chenu rejects Rozwadowski's thesis as a forced reading. Cf. " Aux Origines de la Science Moderne," in *Revue des Sc. Phil, et Theol.,* XXIX (1940), 217, note. A careful consideration of the above-quoted texts will show that they are all perfectly consistent with the Aristotelian theory, and there is no reason to suppose that St. Thomas held the impetus theory which was developed later. However, the theory of impetus is a clear development of his principles.

[31] Text edited from the MSS by Maier, *Zwei Grundprobleme,* pp. 166-180.

[8!] *Ibid.,* line 305, p. 174.

[83] Cf. *ibid.,* lines 313-359, pp. 175-6.

[81] " Movens enim sive agens non confert ipsi mobili passo vim [sive]

Jean Buridan, twice Rector of the University of Paris between 1328 and 1340, reached the same conclusions, but it is most probable that he did so independently of Marchia's teaching. In his *Quaestiones super octo libros Physicorum*[35] and in his *Quaestiones de Caelo et Mundo*,[se] he considers the Platonic and Aristotelian theories of projectile motion, but both seem to offer great difficulty. He points out that the Aristotelian theory cannot account for the rotational movement of a grindstone or a disk, for the motion continues even when a covering is placed close to the bodies, thus cutting off the air. Furthermore, a stone can be thrown farther than a pebble, while violent beating of the air will not move the stone. Therefore, he concludes that the mover must impress a certain *impetus* upon the body itself by which it continues to move until overcome by the resistance of the air and natural gravity.[37] And like Marchia he insists that the impetus is "sibi [corpori] violentus et innaturalis, quia suae naturae formali disconveniens et a principio ex- trinseco violenter impressus, et quod natura ipsius gravis incli- nat ad motum oppositum et ad corruptionem ipsius impetus."[38]

perfectionem aliquam naturalem sive [sibi?] intrinsecam, nec etiam confert vim sive perfectionem aliquam accidentalem et extrinsecam sibi convenien- tem, sed magis dispositionem sibi convenientem auferre, dando enim quod sibi disconveniens est et contra eius naturalem inclinationem aufert quod conveniens est." *Ibid.,* lines 336-343.

[86] Paris 1509, Lib VIII, q. 12; this question about which we are concerned was critically edited by Maier, *op. cit.,* pp. 207-214.

[88]Edited by Ernest A. Moody (Cambridge, Mass.), 1942, Lib. II, q. 12-13, pp. 176-184; Lib. Ill, q. 2, pp. 240-3.

[87] " Ideo videtur mihi dicendum, quod motor movendo mobile imprimit sibi quendam impetum vel quandam vim motivam illius mobilis ad illam partem ad quam motor movebat ipsum, sive sursum sive deorsum sive lateraliter vel circulariter, et quanto motor movet illud mobile velocius tanto imprimet ei fortiorem impetus . . . Sed per aerem resistentem et per gravitatem lapidis inclinantem ad contrarium eius ad quod impetus est natus movere, ille impetus continue remittitur." *Ibid.,* lines 124-132, p. 211; cf. *Quaestiones de Caelo et Mundo,* lib. II, q. 13, line 34 (p. 183) — line 7 (p. 184) ; Lib. Ill, q. 2, line 18-39 (p. 243).

[38] *Quaest. sup. oct. lib. Physicorum,* Lib. VIII, q. 12, ed. Maier, *op. cit.,* lines 198-202.

Albert of Saxony and Marsilius of Inghen likewise teach that a certain force is given to the body by which it moves, but they insist that this "accidental and extrinsic force" is violent and therefore continually decreases until finally it is destroyed.[39] This became the common "Aristotelian" teaching throughout the 15th and 16th centuries. Since the theory of impetus is actually consistent with the principles of Aristotle, later scholastics such as Laurence Londorius, the first Rector of St. Andrew's, Augustine Nipho, Cardinal Cajetan, Alexander Pic- colominus, and Scaliger interpreted Aristotle's words in a wide sense consistent with the theory. Thomists such as Capreolus and Dominic de Soto claimed it as the " opinion of St. Thomas."[40] Some writers of the 16th century, however, conceived the impetus as a *mover.*[41] Against such a conception Dominic de Soto argues that the impetus cannot be a *mover,* the *efficient cause* of violent motion, for this would be to conceive the body as living. Rather it is the *instrument* of the agent who is the efficient cause.[42] He points out the analogy between impetus and nature, for just as the "cause" of natural activity is the progenitor and not " nature," so too the " cause " of violent motion is the agent and not the " impetus." [43] Thus

[30] Cf. Marsilius of Inghen: " Et si quaeras quare impetus sic ultra non sufficit movere, respondetur quod hoc est, quia est violentus corporibus motis, quae ipsum continue remittuntur et tandem corrumpunt." Text ed. Maier, lines 141-3, p. 283.

[40] Capreoli, *Defensiones Theologiae D. Thomae,* Sent. II, dist. 6, q. 1, a. 3; Dominici de Soto, *Super octo libros Physicorum Quaestiones* (Salamanca, 1551), Lib. VIII, q. 3, fol. 103vff.

[41] E. g., Girolamo Cardano: " Cum supponitur quod omne quod movetur ab alio movetur, verissimum est. Sed illud quod movet est impetus ac- quisitus, sicut calor in aqua, qui est ibi praeter naturam ab igne inductus et tamen igne sublato manum tangentis exurit." *De subtilitate rerum,* Lib. XXI (Lyon, 1551), p. 90.

[42] " Impetus ergo quia non est suppositum, non agit, sed est virtus agentis, puta motoris." Dominici de Soto, *op. cit.,* fol. 104v-105r.

[43] " . . . pro coperto reliquisse ex analogia gravium et levium, quae est prima ratio affirmandi huiusmodi impetum. Nempe quod sicut generans grave tribuit illi naturalem qualitatem, quae est gravitas, qua illud per- movet usque ad centrum, sic et proiciens impingat proiecto quo ipsum

impetus is a foreign and borrowed quality which automatically acts without being a "mover," a quality which necessarily diminishes due to the opposing natural forces.

From this it is clear that the theory of impetus is strictly an Aristotelian development. Not only was it developed within the framework of Aristotelianism, but it follows from Aristotle's principles and is consistent with experience. It safeguards the distinction between natural and compulsory motion, for the impetus always remains an alien and extrinsic quality, even though foisted upon the projectile, while nature is a permanent and radical source of characteristic behavior. Furthermore, the theory embodies the principle of finality, for nature intrinsically strives towards its own fulfillment and, therefore, strives to overcome the alien force; the only finality involved in impetus is that which is given by the extrinsic source of projection. This is very different from the principle of inertia, which not only eliminates the distinction between natural and compulsory motion but destroys the notion of finality as well.

II. The Principle of Inertia

During the 16th century a new philosophical spirit emerged, anti-Aristotelian in character. This spirit seems to have originated among logicians who wished to replace traditional logic with mathematics.[44] But with Cardano, Benedetti, Telesio, Bruno, and Galileo, this spirit appeared in natural philosophy as well. Particularly in questions of projectile motion the new .scientists took occasion to attack Aristotle.[45] In their minds the

eminus moveat." *Ibid.,* fol. 104v. See our previous article, " The Concept of Nature," in THE NEW SCHOLASTICISM, *art. cit.*

"Although there were earlier works of this nature, Peter Ramus (1515- 1572) exercised the most noticeable influence, mainly through his *Dia- lecticae Institutiones.* His best known followers were Sturm in Germany, Arminius in Holland, du Naniel in Belgium, and Temple in England.

[45] Cf. Bernardino Telesio, *De rerum natura iuxta propria principia,* 2nd ed. (Naples, 1570), Lib. I, cap. 46, fol. 32v; Giordano Bruno, *Camoeracensis Acrotismus, seu Rationes articulorum adversus Peripateticos Parisiis pro*

scholastic theory of impetus was conceived in a *quantitative* manner; and it is this new theory which has become known as the principle of inertia.[46]

Giovanni Benedetti (1530-90) had already insisted that every body, naturally falling or projected, tends to move in a straight line. But it was Galileo (1564-1642) who first formulated the principle of inertia. In his *Discourses on the Two New Sciences,* the third day, he assumes that the momentum of a given body falling down an inclined plane is proportional only to the vertical distance and independent of the inclination; from this he concludes that a body falling down one plane would acquire momentum which would carry it up another to the same height. The fact that the descent and ascent of a pendulum are exactly equal regardless of the length of the cord and of the weight of the bob are adduced to confirm his view.[47] The momentum of a falling body is accelerated by gravity; it is retarded and eventually overcome by an equal gravity. But if a body moved along a horizontal plane where all causes of acceleration or retardation were absent, its motion would be perpetual and uniform. Thus Galileo says, " Any velocity once received by a body is perpetually maintained as long as the external causes of acceleration or retardation are removed, a condition which is found only on horizontal planes."[48] On the fourth day Gali-

positorum, Opera Omnia Latina (Naples, 1879), I, 138. Even in his youthful work *De Motu* (c. 1590) Galileo begins the chapter on projectiles as follows: " Aristoteles, sicut fere in omnibus quae de motu locali scripsit, in hac etiam quaestione vero contrarium scripsit." Ed. Nazionale, *Opera Omnia,* I, 307.

[48] Cf. A. Maier, *op. cit.,* 303-314; also *Die Vorldufer Galileis in l'f. Jahr- hundert, ed. cit.,* 132-154.

[47] Cf. Galileo, *Discorsi e Dimostrazioni Mathematiche intorno a Due Nuove Scienze attenenti alia Meccanica, et ai Movimenti Locali,* Giornata Terza, *Opere di Galileo Galilei* (Padua, 1744), III, 96.

[48] ". . . velocitas gradus, quicunque in mobili reperiatur, est in illo suapte natura indelebiter impressus, dum externae causae accelerationis, aut retardationis tollantur, quod in solo horizontali piano contingit . . . Ex quo pariter sequitur, motus in solo horizontali esse quoque eternum: si enim est aequabilis, non debilitatur, aut remittitur, et multo minus

leo considers the movement of projectiles. He imagines a perfectly round body projected along a horizontal plane where all adverse forces are removed. He concludes that according to his previous arguments the velocity of the projectile would remain uniform and perpetual if the plane were extended to infinity.[49] Thus the *impeto* as such is a uniform velocity in a straight line which is accelerated or retarded only by extrinsic forces; were it not for these forces, the velocity would remain constant perpetually.

For Galileo the *impeto,* or *momento* is not a quality by which motion takes place, as was held by the scholastics, but the *quantity of motion* measured by the mass times the velocity (*mv*). Rather than an alien source of violent motion, it is the measure of all motion. By considering only the quantitative aspect of motion he reduces both " natural " and " violent " motion to the same category of impetus so that the distinction ceases to have meaning. The important point to notice is that Galileo is not concerned with explaining the existence of motion, but only with the *change* or cessation of motion. For him it is not the continuation of motion which needs to be explained but change of direction and velocity. Motion which does not involve change of direction or velocity is thus called "inertial motion"; and the resistance to this change is commonly called the " force " of inertia.

About the same time Isaac Beeckman, the close friend of Descartes, expressed the principle of inertia clearly when he wrote in his *Journal,* " A thing once moved would not come to rest but for some external impediment."[50] Christian Huygens

tollitur." *Discorsi,* Giornata Terza, prob. IX, prop. 23, Scholium, *ed. cit.,* p. 123.

[49] ""Mobile quoddam super planum horizontale projeetum mente concipio omni secluso impedimento: iam constat ex his, quae fusius alibi dicta sunt, illius motum aequabilem, et perpetuum super ipso piano futurum esse, si planum in infinitum extendatur." *Ibid.,* Ill, 141.

[50] " Omnis res semel mota nunquam quiescit nisi propter externum impedimentum." quoted by Maier, *Zwei Grundprobleme, ed. cit.,* p. 311.

had a clearer idea of the principle and formulated it as an " hypothesis " for his work on the pendulum.[51] Descartes (1596-1650), however, extended the principle to cover the whole of natural philosophy by making it " the first law of nature." [52] The principle of inertia reached its classical formulation in Isaac Newton's *Principia*: "Every body continues in its state of rest or of uniform motion in a straight line, unless it is compelled to change that state by forces impressed upon it." [53]

The principle of inertia is, indeed, as Whitehead calls it, " the first article of the creed of science." [54] But the numerous and varied studies, criticisms, and justifications of this principle show that its meaning is not as clear as one might hope.[55] Einstein's criticism of the Newtonian formulation and the "unification of inertia and gravitation" in relativity physics have obscured even more the meaning of the principle.[56] It is clear that the Galilean and Newtonian theory established an entirely new outlook on nature, but as Whitehead points out, " it is noticeable that no reason was produced in the 17th cen

[61] " Si gravitas non esaet, neque aer motui corporum officeret, unum- quodque eorum, acceptum semel motum continuaturum velocitate aequabili, secundum lineam rectam." *Horologium Oscillatorium,* Part II, Hypothesis, Paris 1693.

[62] " Prima lex naturae: quod unaquaque res quantum in se est, semper in eodem statu perseveret; sicque quod semel movetur, semper moveri pergat." *Principia Philosophiae* (1644), P. II, art. 37, *Oeuvres,* ed. Adam- Tannery, VIII, 62.

[58] " Corpus omne perseverare in statu suo quiescendi vel movendi uni- formiter in directum, nisi quatenus illud a viribus impressis cogitur statum suum mutare." *Philosophiae Naturalis Principia Uathematica,* Law I. The first ed. of this work was printed in London 1687; modern English trans. of the 2nd ed., F. Cajori (Berkeley, 1947). For the background of Newton's 2nd ed., *ibid.,* pp. 628-632.

[54] *Essays in Science and Philosophy* (London, 1948), p. 171.

[55] Cf. G. Whitrow, " On the Foundations of Dynamics," *British J. for the Phil, of Sc.,* I (1950), 92 ff.; R. J. Nogar, "Toward a Physical Theory," The New Scholasticism, XXV (1951), 397-438.

[56] Cf. A. S. Eddington, *Space, Time, and Gravitation* (Cambridge, 1920), pp. 136-151; *The Nature of the Physical World* (London, 1947), pp. 115-139.

tury for the Galilean as distinct from the Aristotelian position." [57] Since the principle of inertia played such an important role, it is necessary to consider not only its relation to Aristotelian natural philosophy, but also the meaning and logical foundation of the principle.

It is clear that the doctrine of inertia had its rise in the science of mechanics. Mechanics in its proper sense is a practical science of determining the amount of force to be applied in order to produce a certain effect. This is clear in such elementary problems as the lever, equilibrium, displacement, and so forth, in which the resistance afforded by a body is taken into aucount (force of inertia) or the irrelevant state of a body is disregarded (principle of inertia).[58] In this sense the principle was not first discovered by Galileo, but was already recognized by Stevinus, Da Vinci, and Archimedes. However, it is one thing to justify the principle in mechanics, and quite another to establish it as " the first law of nature."

Foundation of the Principle

What is the logical foundation for the principle of inertia? Is it self-evident that every body continues in its state of rest, or of uniform motion in a straight line, except so far as it may be compelled by force to change that state? Usually the proposition is stated as immediately evident. It is pointed out that a block of wood thrown along a rough road slides only a short distance, along a floor a longer distance, and along ice still farther. "From examples like these, it is reasoned that if friction could be eliminated entirely, which cannot actually be done, a body once set into motion on a level surface would continue to move indefinitely with undiminished velocity; thus uniform motion is a natural condition." [59] But such reasoning

[57] *Science and the Modern World* (Cambridge, 1946), p. 60.

[58] This point is explained at length below, pp. 56 ff.

[68] *Physics,* E. Hausmann and E. P. Slack, 3rd ed. (New York, 1948). " Intuitively, also we recognize that were it not for disturbing and ex-

neither proves the proposition nor manifests its self-evidence. The fact that a body continues longer over a smoother surface does not prove that, were the surface infinitely smooth, it would continue indefinitely.[60] Nor is this self-evident. It assumes that the body itself is a null factor and that external factors can be excluded to render the motion uniform. In actual experience there is no manifestation of the first assumption, for in all evident phenomena such motion is resisted, and this resistance is relative to the body.[61] In other words, actual experience is against such an assumption. Relativity physics denies the second assumption, for bodies are always in a gravitational field— and indeed, constitute it; thus the motion would not be uniform, but accelerated.[62] It seems clear, then, that the usual examples

traneous forces, especially friction, this constant speed in a straight line might be maintained forever." H. B. Lemon, *From Galileo to the Nuclear Age* (Chicago, 1946), p. 6.

[0] This argument by extrusion can be answered on experimental grounds. Increasing the smoothness of two surfaces in contact does not reduce their friction indefinitely, for a point is reached where further polishing increases the friction. Cf. Fred. Palmer, " Friction," *Scientific American,* CLXXXIV (1951), 54-59.

[61] Jean Buridan suggested that since the heavenly bodies do not offer resistance (an Aristotelian doctrine, cf. *De Coelo,* II, c. 1, 283b26-284a25), the original impetus given to them by God would be sufficient to keep them moving forever. " Posset dici quod non apparet necessitas ponendi huiusmodi intelligentias, quia diceretur quod Deus quando creavit mun- dum, unumquemque orbium caelestium movit sicut sibi placuit et movendo eos impressit sibi impetus moventes eos absque hoc quod amplius moveret eos, nisi per modum generalis influentiae, sicut ipse concurrit coagendo ad omnia quae aguntur. . . . Et illi impetus impressi corporibus caelesti- bus non postea remittebantur vel corrumpebantur, quia non erat inclinatio corporum caelestium ad alios motus, nec erat resistentia quae esset cor- ruptiva vel repressiva illius impetus. Sed hoc non dico assertive, sed ut a dominis theologis petam quod in illis doceant me, quomodo possunt haec fieri." *QQ. in Till Physicorum,* q. 12, ed. Maier in *Zioei Grundprobleme,* lines 170-184; also in *QQ. de Coelo et Mundo,* Lib. II, q. 12, ed. Moody, pp. 180-1.

[62] Eddington says pointedly that the teacher " glosses over the point that if there were no interference with the motion—if the ice were abolished altogether—the motion would be by no means uniform, but like that of a falling body." *Space, Time, and Gravitation, ed. cit.,* p. 136.

given to display the "self-evidence" of this principle are unsatisfactory.

In the early days of modern science it was thought that the principle of inertia was philosophically demonstrated and experimentally verified.[63] In Descartes' system the principle is founded on the conservation of momentum. He alleged that in the beginning God created not only matter, but also a determined *quantitas motus,* which could neither be augmented nor decreased.[64] This he thinks is necessary, for otherwise God would have to continue creating motion; and this is contrary to His immutability! Throughout the entire universe the " quantity of motion" remains constant so that when one body is at rest, another is in motion; when one moves twice as fast, another moves half as fast as previously.[65] Descartes determined the " quantity of motion " to be measurable as the product of the mass moved into the velocity with which it is moved, that is, Galileo's momentum, *mv.* Change, then was to be explained as the transference of momentum from one body to another through impact. Since the quantity of motion in the universe *(mv)* must be constant, *id quod movetur, quantum in se est, semper moveri*,[66] Thus for Descartes the principle of inertia was based upon the conservation of momentum *(mv),* conservation was thought necessary because of the immutability of God.

[88] Cf. H. Poincare, *Science and Hypothesis* (London, 1905), 94-95.

[84] " Deum esse primariam motus causam: et eandem semper motus quantitatem in universo conservare." *Prin. Phil.,* P. II, art. 36, *ed cit.,* VIII, 61.

[80] " Ita scilicet ut putemus, cum una pars materiae duplo celerius movetur quam altera, et haec altera duplo maior est quam prior, tan- tundem motus- esse in minore quam in maiore; ac quanto motus unius partis lentior sit, tanto motum alicuius alterius ipsi aequalis fieri celeri- orem." *Ibid.,* p. 61.

[88] *Prin. Phil.,* P. II, art. 37, *ed cit.,* VIII, 62. Spinoza's presentation of Descartes' argument, *more geometrico demonstratum,* shows clearly the supposed logical foundation of the principle of inertia. " (Propositio XIX: Unaquaeque res, quatenus simplex et indivisa est, et in se sola considera- tur, quantum in se est, semper in eodem statu perseverat.) Demonstratio: cum nihil sit in aliquo statu, nisi ex solo Dei consursu (per prop. 12.

Leibniz (1646-1716), however, pointed out that momentum is not constant in the universe, for it cannot be shown that every body imparts the same quantity of motion to some other body.[67] Furthermore, Leibniz maintained that it is not momentum which accounts for movement, but rather a certain *vis viva, lebendige Kraft,* which is measured not by *mv,* but by mass times the velocity squared (mv^2). He maintained that it was *vis viva* which accounted for motion in the world and which, furthermore, remained constant throughout the universe.[68] Leibniz is really pointing out here the difference between momentum and what has become known as energy. The important point is that -Leibniz bases the principle of inertia on the conservation of energy, instead of on Descartes' momentum.[69] However, as Leibniz denies any *real* interaction between the unextended monads which make up the real world, the conservation of energy is a *phenomenological principle* which depends upon " pre-established harmony " in which God alone is the true cause. In the *Discours de Metaphysique,* § 18, Leibniz says:

part. I) ; et Deus in suis operibus sit summe constans (per Coroll. Propos. 20. part. I) ; si ad nullas causas externas, particulares scilicet, attendamus, sed rem in se sola consideramus, affirmandum erit, quod ilia, quantum in se est, in statu suo quo est, semper perseverat. Q. E. D." Spinoza, *Renati Des Cartes Principiorum Philosophiae More Geometrico demon- stratae, Opera,* ed. Van Vloten et Land (The Hague, 1914), IV, 159.

[e7] Principally in his *Systeme nouveau de la nature,* ed. by C. J. Ger- hardt, *Die philosophischen Schriften von G. W. Leibnitz,* (Berlin, 1S90),
IV. For the controversy between the followers of Descartes and Leibniz on this point, cf. H. \V. B. Joseph, *Lectures on the Philosophy of Leibniz* (Oxford, 1949), pp. 27-54.

[9] ". . . eandem motricis potentiae summam in natura conservari." Leibniz called this active force *vis viva* because it seemed to multiply itself in the square of the velocity. Prof. Joseph points out that the importance of the squared velocity for Leibniz was that it led to some reality beyond mere mechanics; Leibniz was fully aware that a velocity could not be really (physically) squared, but that it was a mental process which yielded a number corresponding to a physical effect. Therefore, the reality which could not be attained in Cartesian mechanics, had to be sought in his " metaphysical " monads. Cf. Joseph, *op. cit.,* pp. 41-61.

•• Cf. Leibniz, Letter to Voider, *Philosophische Schriften,* II, 170.

Although all the particular phenomena of nature can be explained mathematically or mechanically by those who understand them, yet nevertheless, the general principles of corporeal nature and even of mechanics are rather metaphysical than geometrical, and belong to certain forms or indivisible natures, as the causes of what appears, than to corporeal or extended mass.[70]

Descartes realized that his doctrine of conservation seemed to preclude every activity of the soul upon the body. To reconcile the conservation of momentum in the world and the activity of the soul on the pineal gland, Descartes maintained that the soul cannot give momentum to the body but only change of direction. In answering this " ingenious " distinction, Leibniz points out that even change of direction requires a force, but he acknowledges the impossibility of the soul's acting upon the body even to change the direction of the " animal spirits "— " a thing which appears as inconceivable as to say that it gives them movement, at least unless one has recourse as I do, to the pre-established harmony." [71] For Leibniz the phenomenological world may be described through mechanical laws, but the real world and even the foundation of mechanical laws are to be found in the realms beyond mechanics. Furthermore, the conservation of *vis viva* in the world depends upon the will of God.

Even Isaac Newton, as will be shown more clearly in the next article,[72] insisted that mechanical laws applied in the universe *as though* bodies themselves were the *cause* of such motion. Newton tried to distinguish very carefully between the mathematical principles which could describe the activity of nature and the " metaphysical reality " about which he would make no " hypotheses " but in which he firmly believed. Under the direct influence of Henry More's Platonism and Jacob Boehme's mysticism he attributed the real cause of material effects to

[70] Leibniz, *Philosophische Schriften,* IV, 444.

[71] Leibniz, *Systeme nouveau, Phil. Schriften,* IV, 497.

[73] " Space and Gravitation " to be published in the next issue.

God, Who operates through space, His " Sensorium." [16] Prof. Snow summarizes Newton's philosophy as follows: "While the motion of matter follows the general laws of mechanics, the real or final cause of motion does not, but a Divine Providence creates, conserves, and regulates motion, in order that 'bodies may not go off their course [74] Newton, however, did believe that the first two laws of motion were substantiated by Galileo's work on the inclined plane and by Huygens' work on the pendulum.[75]

In the 17th century, therefore, the principle of inertia was thought to rest on conservation of momentum or energy. This latter principle was thought to be based upon: i) certain experimental phenomena, namely, the inclined plane and the pendulum; and ii) upon "metaphysical" (or theological) considerations. But it is clear that the experiments on the inclined plane and on the pendulum are strictly mechanical in the proper sense of the word; they neither manifest the self-evidence of the principle of inertia, nor do they demonstrate it. Much less do these experiments establish it as a universal law of nature. It is true that the so-called principle is *involved* in these and other experiments, as will be shown later, but this is not to establish

[73] The most extensive study of Newton's personal philosophy has been made by Prof. A. J. Snow of Northwestern University in his *Matter and Gravity in Newton's Physical Philosophy* (London, 1926). Arguing against Descartes, Henry More insisted that although the material effects of nature are mechanical, the real cause must be immaterial and spiritual—by penetrating matter, it is the source of motion, of cohesion, or separation of parts of bodies; it is the directing force of all motion, animate and inanimate. (Cf. More, *Immortality of the Soul,* Bk. I, chap. ii, art. 11-12.) More attributed " spiritual substance " to God, the angels, the mind of man, and to space, the extension and "sensorium" of God. (Cf. More, *Enchiridion Metaphysicum,* chap. 28, par. 2; chap. 8; also preface to the *Immortality of the Soul.)*

[74] A. J. Snow, *op. cit.,* p. 210. The phrase "final cause" is used in the accepted 17th cent, sense of "metaphysical"; ever since Francis Bacon relegated the study of final causes to metaphysics, the phrase had become identical with metaphysical among English writers.

[75] Cf. Newton, *Principia,* Scholium to Definitions, *ed. cit.,* pp. 21-28.

it as the first law of nature. It should not he necessary to consider the "metaphysical" (or theological) arguments which were adduced in defense of the principle, as hardly anyone today relies upon them, at least in the present context.

When Immanuel Kant tried to establish the universality of Newtonian physics in the face of Hume's scepticism, he reduced the principles of mathematics and natural philosophy to *a priori* judgments or conditions of the mind. Thus he believes the principles of inertia and conservation to be universally valid, because they are demanded by the law of causality, an *a priori* necessity which the mind imposes on events. But by the law of causality Kant means that " every change must have a cause "; this cause is not only extrinsic but must act continually upon the body whenever there is a change of *state,* that is, a change from rest to motion or a change in velocity.[76] In other words, Kant's idea of causality presupposes the validity of the principle of inertia, as his very concept of causality implies.[77]

With the development of thermodynamics in the last century and the universal application of the conservation of energy by Helmholtz (1821-1894), it was generally believed that the principle of inertia had universal validity.[78] But Poincare

[78] Cf. *ICritik der reinen Vernunft,* B. II, Kap. II, sect. 3, 3 A.

[77] It may be pointed out that in Kant's scheme of the sciences there is no room for natural philosophy in the Aristotelian sense of the word. By " pure natural science " Kant understands the application of mathematics to phenomena, or what the Aristotelian would call mathematical physics. (Cf. Kant, *Prologomena,* § 14.) Thus it is not surprising that his concept of causality should be that of the mathematical physicist, which concept implies the principle of inertia. Cf. Josef Schmucker, " Der Ein- fluss des Newtonschen Weltbildes auf die Philosophie Kants," in *Philosophisches Jahrbuch,* LXI (1951), 52-58.

[78] Cf. Hermann von Helmholtz, " On the Conservation of Force," in *Harvard Classics* (Scientific Papers), XXX, 181-220; see also Ernst Mach's *History and Root of the Principle of the Conservation of Energy* (Chicago, 1918). Mach however believes that the principle has a more universal, i. e., non-mechanical, validity than Helmholtz maintained (cf. pp. 38-39; 59-74). For Mach the principle of conservation is based on the theorem of excluded perpetual motion; this in turn he derives from another form of the causal principle, viz., " it is not possible to create work out of nothing." But

pointed out that the laws of thermodynamics are valid only in a particular set of phenomena and cannot be extended to the whole universe by giving the laws an absolute meaning.[79] Poincare himself believed that the principle of inertia is neither imposed on the mind *a priori,* nor universally demonstrated. Biit he adds, " This law, verified experimentally in some particular cases, may be extended fearlessly to the most general cases; for we know that in these general cases it can neither be confirmed nor contradicted by experiments." [80]

From these considerations the following points seem to emerge, i) *The principle of inertia is not self-evident.* While it is true we may conceive or imagine a being with uniform motion in a straight line, unable to change except by an external agent, no such being can possibly exist in the world we know, ii) *The principle is not demonstrated as a universal law of nature.* Philosophical reasoning does not demonstrate it, for the data of human experience are contrary to the statement of the principle; the various branches of physical science which "involve" the principle cover only particular phenomena, that is, limiting cases, and therefore cannot manifest it for the whole of natural reality, iii) *The principle is not even demonstrated in any of the existing branches of physical science.* While it is true that the principle seems to be " involved " in many particular cases, so that we can say with Poincare that it is " verified experimentally in some particular cases," there is no actual proof of it as a " law." Rather than proving the principle, the mechanical and mathematical science of nature *assumes* it. Yet there is a necessity in this: the mathematical sciences must assume it, if they are to remain mathematical. But this necessity of assuming it can be brought out only by explaining the actual meaning of the principle of inertia.

a careful study of Mach's arguments will show that this statement is to be understood in a mathematical, and not a philosophical context.

H. Poincar6, *Science and Hypothesis,* pp. 129-135.

[80] *Ibid.,* p. 97.

MEANING OF THE PRINCIPLE

When discussing- the meaning of this " principle," care must be taken not to confuse it with secondary factors, which although very important in mathematical physics, do not express the essential meaning of the principle. For example, the fundamental idea of the principle should not be confused with a " force of resisting " an external deterrent to the actual course of a body. Certainly every natural body in a gravitational field will have a *vis resistendi,* but this is not what is meant by the "law" of inertia. Nor should the law be limited to the particular phrase " uniform motion," that is, motion in a " straight line."[81] Although this aspect of Newton's formulation has important consequences in *determining* the motion of a body, the essential idea is that a body once moved continues to move— whether with uniform or accelerated motion is of secondary importance, as far as understanding the principle is concerned. Relativity physics has brought out very clearly the ambiguity of this part of Newton's proposition; since all measurements of moving bodies depend upon the position and condition of the observer, how are we to know whether the motion is uniform or accelerated? Nevertheless, the essential idea implied in the principle of inertia remains even in relativity physics.

It is commonly claimed that the greatest triumph of the 17th century was to rid the celestial spheres of spiritual movers and to effect the unification of celestial and terrestrial mechanics. As Prof. Butterfield puts it, " The modern law of inertia, the modern theory of motion, is the greatest factor which in the seventeenth century helped to drive the spirits out of the world and open the way to a universe that ran like a piece of clock

[81] Strictly speaking uniform motion and motion in a straight line are identical in the language of physics inasmuch as any change in either requires an external agent. But for the sake of clarity both expressions are frequently used in these articles as though they were distinct.

work." [82] An examination of how this was done and what it means will lead to a clarification of the concept of inertia.

In the Aristotelian philosophy of nature a distinction is drawn between celestial and terrestrial bodies. The distinction fundamentally lies in the different ways the two are moved: terrestrial bodies naturally come to rest, the celestial do not. As was pointed out previously, nature as an active principle necessarily involves some *finality,* "for since nature always tends determinately towards one [perfection], not being indifferently suited to many, it is impossible that a given nature aim at motion for its own sake."[83] With regard to motion in place a given nature tends toward a suitable place, a congenial environment, in which it is relatively at rest. But we see that the heavenly bodies move continually without a particular place in which to rest. Even if it could be shown that the celestial motions are gradually coming to rest, such a rest would not be a good thing for either the planet or the universe, so that this cessation of movement could not be called the natural aim of celestial motion. Whether the earth is considered to be one of the moving planets or not does not alter the case: bodies on this earth must have a determined place for survival, while planetary bodies move continuously in their orbits.[84] Since celestial bodies have no intrinsic finality accruing to them in rest, St. Thomas concludes that their motion arises not from an intrinsic *active* (formal) principle, but from an intrinsic *passive* (material) principle, which needs to be continually moved by some non-corporeal being.[85] This was the real basis for distinguishing

[82] *Origins of Modern Science* (London, 1951), p. 7; see also C. Singer, *A Short History of Science* (Oxford, 1943), pp. 212-217.

[83] " Cum enim natura semper in unum tendat determinate, non se habeas ad multa, impoasibile est quod aliqua natura inclinet ad motum secundum se ipsum." St. Thomas, *De Pot.,* V, 5.

[84] " Caelum autem non pervenit suo motu in aliquid *ubi,* ad quod per suam naturam inclinetur, quia quodilibet *ubi* est principium et finis motus." *Ibid.*-, cf. *Sum. cont. Gent.,* Ill, c. 23; *In II De Coelo,* lect. 18, n. 1.

[83] " Unde non potest esse suus motus naturalis quasi sequens aliquam

the two classes of bodies—a functional division. All the other properties attributed to the heavenly bodies are secondary. They were thought to be " ingenerable and incorruptible," because no generation or corruption was observed.[86] They were thought to be of a different element to account for this.[87] This teaching was the general, although not the universal, opinion of medieval philosophers.[88]

From the earliest days of astronomy men have tried to determine the relative positions, periods, and velocities of the heavenly bodies. The astronomers assumed the motion of the planets and attempted no explanation of why they moved; this

inclinationem naturalis virtutis inliaerentis, sicut sursum ferri est motus naturalis ignis." *De Pot.,* V, 5; cf. ad 12; II *Phys.,* lect. 1, n. 4. Whether the heavenly bodies are animated as Aristotle believed, or moved extrinsically by God or angels; does not affect the immediate point, for in any of these cases continual motion can be explained, for the finality is in the mover. But St. Thomas insists, " *Non autem, esset via solvendi, si moverentur per solum naturae impetum, sicut corpora gravia et levia." In II De Coelo,* lect. 18, n. 1.

[86] Cf. St. Thomas, *In I De Coelo,* lect. 7, n. 6.

[87] Cf. St. Thomas, *In I De Coelo,* lect. 4.

[88] Even in the 13th century there were some who dispensed with the need for angels to move the heavenly bodies and who explained this motion as " a natural inclination to move in circular motion." An *active* inclination toward such motion would dispense with a continual mover, as has been explained. Notably Robert Kilwardby, O.P., defends this position of *quidam* in his response to the 43 questions sent by the Master General, John of Vercelli, in 1271. Cf. text of q. 2, n. 3 from Bordeaux Ms. 131 published by M.-D. Chenu: " Aux Origines de la Science moderne," in *Revue des Sc. Phil, et Theol.,* XXIX (1940), 211-212; also " Les reponses de S. Thomas et de Kilwardby a la consultation de Jean de Verceil," in *Melanges Mandonnet* (Paris, 1930), I, 191-222. Fr. Daniel Callus, 0. P., has pointed out that this idea can be traced to the earliest days of Aristote- lianism in Oxford; some 60 years before Kilwardby John Blund expounded the same doctrine in his unpublished *De Anima,* now being collated by Fr. Callus. Cf. D. A. Callus, " The treatise of John Blund On the Soul," Autour d'Aristote: Receuil d'Etudes de Philosophie Ancienne et Medieval Offert a Monseigneur A. Mansion (Louvain, 1955), 471-495. This theory was not unknown in the 14th century, for Jean Burdian and Albert of Saxony defend it as a probability (cf. above, note 61). Likewise Copernicus tends to explain the circular movement of the earth and other planets by a natural inclination of the form; cf. *De Revolutions Orbium Caelestium,* Lib.
I, cap. iv and viii, ed. Thorn, pp. 14-15, 21-24.

was the task of philosophers. Even Copernicus did not attempt to explain why the planets moved as they do; he merely assumed that this was their nature.

Descartes, however, believed that a completely mechanical explanation of the universe was possible, and he sought a physical cause to keep the heavenly bodies in motion. This cause he found in vortices, a subtle material fluid which whirled around carrying the heavier bodies with it.[80] The Cartesian vortices were proposed as a causal explanation of both terrestrial gravitation and celestial movement.[90] Johannes Kepler (1571-1630) discovered his three famous laws from the observatal data amassed by Tycho Brahe; they are strictly empirical laws, in so far as one may call an astronomical law empirical. Nevertheless, he tried to find some physical force emanating from the sun which could supply the planet's motion in an elliptic path. In the introduction to his *Astronomia Nova* of 1609 Kepler proposes the hypothesis that the sun propagates into the depths of the universe a *species immateriata* of itself.[91] Giovanni Borelli (1608-79) followed Kepler in the view that the planets need a force emanating from the sun to push them around in their orbits, and he added that if it were not for this centrifugal force, the planets would fall into the sun by the effect of gravity, which he described as a *natural instinct* in bodies to fall towards the sun.[92] But all such attempts to find a physical cause impelling the celestial bodies lacked astronomical verification, as they arose mainly from a philosophical desire to unite all physical phenomena in a mechanical explanation of movement.

The great triumph of Newton was that he reached the goal

[8'] Cf. Descartes, *Principia Philosophiae,* III, art. 53-157, *ed. cit.,* 106-202.

[•°] Cf. Letter LXI, *Oeuvres* I, 314; Letter CLXXIX to Mersenne, *Oeuvres* II, 635; *Prin. Phil.,* P. IV, art. 24, p. 214.

[91] *Opera Omnia Kepleri,* ed. Frisch, III, 156.

Cf. A. Armitage, Borelli's Hypothesis and the Rise of Celestial Mechanics," *Annals of Science,* VI (1948-50), 268-292. This article explains admirably the development of celestial mechanics up to Newton's formulation.

which eluded his contemporaries. The cornerstone of his success was the principle of inertia. Two concepts were very much to the fore during the latter part of the 16th and early part of the 17th centuries: the concepts of centrifugal force and attraction. Giambattista Benedetti, Borelli, Descartes, Hooke, and Huygens had described at great length that the motion of a stone in a sling naturally tends to move along the tangent to the circle described, so that it is the tension in the cord, curbing this tangential motion, which keeps the stone in the arc.[93] The notion of attraction had become popular with the publication of Sir William Gilbert's *De Magnete* in 1600. It was these two ideas that Newton united in his famous proof that the earth attracts the moon in the inverse proportion of its distance, as was required by Kepler's three laws.[94] Since the earth's circumference and the distance of the moon were known, the orbital velocity of the moon could easily be calculated on the basis of the lunar month. The problem was to find out how much the moon would fall were there no centripetal force holding it in its orbit; or in other words, how much force was needed to counteract the velocity of the moon. Newton found that it would fall loi Paris feet per minute, which corresponded to Huygens' figures for the movement of the pendulum.[90] Thus Newton maintained that the attraction, varying inversely as the square of the distance, held good universally, allowing for minor discrepancies.

It is easy to see how important the principle of inertia is in

[83] Cf. A. Armitage, *art. cit.,* p. 275.

[84] Newton, *Principia Mathematica,* Bk. Ill, prop. IV, Theorem 4, ed. Cajori, pp. 407-409; for the derivation of the inverse square law from Kepler's third law, cf. Max Born, *Natural Philosophy of Cause and Chance* (Oxford, 1949), Appendix 2, p. 129.

[83] " And therefore the force by which the moon is retained in its orbit becomes, at the very surface of the earth, equal to the force which we observe in heavy bodies there. And therefore (by Rule 1 and 2) the force by which the moon is retained in its orbit is that very same force which we commonly call gravity." *Ibid.,* ed. Cajori, p. 408. Cf. also F. Cajori, *A History of Physics* (New York, 1916), pp. 56-62.

this demonstration. Newton assumes that the moon does move; he assumes moreover that it would move at a constant rate at a tangent to the circle were it not for the attracting force. The point is to find two quantities which will equate: in this case it is the velocity of the moon and the rate of supposed fall. (The applicability of this equation to terrestrial gravitation establishes the universal law.) In every equation something must be considered irrelevant, that is, something must be assumed as not affecting the quantities. In the present case it is the actual movement of the moon or the observer. Newton assumes that the moon would move with uniform motion in a straight line, *so that motion does not have to be considered in the equation.* Once the quantities are obtained it is as though the bodies were at rest. In other words, the argument begins with considering the velocity (and mass, which is measured through acceleration), but once the quantities have been obtained it is no longer a question of the actual motion but only of the proportionality of these quantities. Thus it must be assumed that every body continues in its state of rest, or of uniform motion in a straight line, except so far as it may be compelled by force to change that state. That is to say, uniform motion, rest, and even actual movement can be considered null factors in the equation, for they do not affect the case. Only new quantities, such as those which change the velocity or direction, have meaning and so must be considered in devising an equation. Thus inertial motion, or an inertial system is one in which certain factors are disregarded.

Exit at this point the question arises as to what is meant by uniform motion in a straight line. Does not this statement presuppose an absolute frame of reference in which this statement has meaning? But if all measurements of time and space are relative to the observer who may or may not be moving in an inertial system, then there are factors which are not null, but definite quantities which must enter into the equation. How are we to know that a certain system is inertial? In the Newtonian

theory this may be answered in two ways: i) it moves with uniform motion if it is not affected by external forces; or ii) it is an actual fact that we can choose a series of co-ordinates with reference to which bodies at rest remain at rest and bodies in motion continue in uniform rectilinear motion. With regard to the first Einstein answers that "it involves an argument in a circle: a mass moves without acceleration if it is sufficiently far from other bodies; we know that it is sufficiently far from other bodies only by the fact that it moves without acceleration." [96] With regard to the second Einstein showed that there is no reason to give preference to an inertial system over one moving with accelerated motion.[97] By identifying inertial and gravitational mass and by showing how a field may be regarded as both inertial (uniform) and gravitational (accelerated), Einstein established his principle of equivalence, that is, a physical event described in an inertial system may be described equivalently in a non-inertial system. In formulating his general theory of relativity, Einstein carries the equivalence of systems to an extreme limit: "All Gaussian four-dimensional co-ordi- nate systems are equally applicable for formulating the general laws of Physics." [98] It is clear, then, as Sir Edmund Whittaker says, "What Einstein's theory really does is to abolish the old idea of gravitation altogether, and to replace it by *the idea of inertial frameworks*."[99] In other words, although relativity physics disagrees as to what is inertial motion, that is as to *what* may be regarded as a null factor, the ultimate agreement lies in the acceptance of something as irrelevant and null in the

[98]A. Einstein, *The Meaning of Relativity* (London, 1950), p. 57. Cf. also A. Eddington, *Space, Time and Gravitation, ed. cit.,* pp. 13G-7.

Cf. A. Einstein, *The Theory of Relativity,* 8th ed. (London, 1924), pp. 59-79; see also L. Silberstein, *The Theory of Relativity,* 2nd ed. (London, 1924), pp. 294-312.

[98] E. Freundlieh, *Einstein's Theory of Gravitation* (London, 1924), pp. 45-61; also essay by Prof. H. L. Brose, *ibid.,* p. 127.

[89] E. Whittaker, *From Euclid to Eddington* (Cambridge, 1949), p. 115. (Italics mine.)

equating of quantities. It is this acknowledgment of the irrelevance, the nullity of certain factors, which constitutes the principle of inertia.

The basis for the principle of inertia lies, therefore, in the nature of mathematical abstraction. The mathematician must equate: a single quantity is of no use to him. In order to equate quantities he must assume the basic irrelevance or nullity of other factors, otherwise there can be no certainty in his equation. The factors which the mathematician considers irrelevant are, as we have seen, motion, rest, constancy, and unaltered directivity; it is only the *change* of these factors which have quantitative value. Thus for the physicist it is not motion and its continuation which need to be explained, but change and cessation of motion—for only these have equational value. The principle of inertia which is necessitated by every equation must exclude the vitality of real existence, spontaneity, motion, and finality. In other words, the logical function of inertia in mathematical abstraction necessarily relinquishes the reality and spontaneity of nature.

To return to the question of spiritual movers, it is clear that the principle of inertia has not done away with their need. It would be more accurate to say that mathematical physics is not concerned with who or what moves the heavenly bodies. A spiritual force moving the planets would be of no use to the mathematician, for he could never get two quantities to equate. But neither is it true to say that the principle of inertia has done away with their need. In the early part of the 17th century physicists tried to find a physical cause to explain the movement; Newton merely disregarded the question and looked for two quantities which could be equated. In Newtonian physics there is no question of a cause, but only of differential equations which are consistent and useful in describing phenomena.[100]

[100] « when we say force is the cause of motion, we are talking metaphysics; and this definition, if we had to be content with it, would be

From what has been said it is clear that the principle of inertia, the foundation of mathematical physics, is neither self- evident, nor demonstrable in any way. The logical basis of the principle lies in the nature of mathematical abstraction, which must leave out of consideration the qualitative and causal content of nature. That is to say, mathematical physics can never attain the ultimate reality of "nature," its spontaneity and intentionality, its qualitative characteristics and causal dependencies—all of which are given in human experience. Furthermore, since mathematical physics abstracts from all these factors, it can say nothing about them; it can neither affirm nor deny their reality, although a mathematician can be led to believe in a reality wider than his abstractions. If, therefore, the concept of nature, as expounded, is justified in human experience, so too is the distinction between natural and compulsory movement. Since these realities are of no use to the mathematician as such, he must reduce whatever he can to the common factor of quantity. But to the natural philosopher, who embraces the *whole* of human experience, the distinction between natural and compulsory motion is of utmost importance. The two pictures of the universe afforded by mathematical abstraction and philosophical experience, far from being incompatible, are the necessary binoculars of physical knowledge.

absolutely fruitless, would lead to absolutely nothing. For a definition to be of any use [in mathematical physics] it must tell us how to measure force." H. Poincare, *Science and Hypothesis, ed. cit.,* p. 98.

CHAPTER IV

Space and Gravitation

THIJS EAR IN our study we have considered nature as a taneous principle of determined behavior, or behavior which is actually " given " in human experience. Since all such determined behavior manifests an intrinsic intentionality of purpose, congruent activities find their explanation within the beings themselves, while the *raison d'etre* of compulsory activity lies in the external force imposed upon nature. Thus in a philosophy of nature, strictly so-called, a fundamental distinction must be made between natural and compulsory movement, for the explanation of these two phenomena is different. Furthermore, we have seen that there is another science, which although considering the same world of nature, reduces all phenomena to quantitative proportions. In this mathematical science of nature spontaneity, finality, and " natural " motion have no meaning, for as such they cannot be quantitatively expressed in the form of equations.

The significance of every science lies in its *explanation.* Every science, if it is to be a science at all, must explain something. It is the different kinds of explanation afforded by the various sciences which distinguish one science from another. This is not to say that every system of philosophy may proffer its own explanation and be just as true as any other explanation. Contradictory explanations of the same phenomenon from the same point of view cannot be equally true. Nature does not tolerate contradictions. But if two sciences look at the same phenomenon from two entirely different points of view, points of view which are both humanly

legitimate, then these two sciences are not contradictory but complementary. Such is the case between a natural and mathematical view of nature. It is because the mathematical view leaves out of consideration the underlying structure of reality and considers only quantitative proportionality that its " explanations " differ so radically from the natural philosopher's. The philosopher of nature must accept *everything* which is given in human experience and his explanation will be in terms of value, purpose, causal structure, and experience. The mathematician can deal only with equations in which the variables seem to affect each other as " efficient causes," but which in reality are only " functional dependencies." [1] Thus a mathematical " explanation " is in terms of a variable quantity, or measure, which necessarily affects a dependent quantity. Such an explanation is not interested in the structure of the phenomenon itself but only in indicating the necessary proportionality involved in the measures. It is the element of necessary proportionality, rather than efficient causality itself which is manifest in mathematical " explanations " of nature.[2] This

[1] " To avoid all these dangers of reading metaphysics into physics it might be well to drop the habit of expressing connections between physical properties in terms of causality. In practice what is actually used is a system of *functional dependencies,* and it may be left to other than physicists to decide, if they wish, the extent to which these can be summarized in any law of causality." M. Johnson, *Time, Knowledge and the Nebulae* (London, 1944), p. 35. See also V. Lenzen, *The Nature of Physical Theory* (New York, 1931), pp. 289-290. St. Thomas very frequently points out that mathematics necessarily abstracts from efficient and final causality. Cf. *In III Meta.,* 4, n. 375; *In Boeth. de Trim.,* V, 4 ad 7; *Summa Theol.* I. 44, 1 ad 3; Jn I *Phys.,* 1, n. 5. In Thomistic terminology the causality actually employed in mathematics by means of functional dependencies reduces to extrinsic formal causality, which is a proportion or proportionality between two patterns, or forms. Cf. St. Thomas, *In III Meta., 4,* nn. 379-381.

[2] Only in this context can one understand the preeminence of " necessity " in the Humean and Kantian search for the foundation of the principle of causality. Cf. D. Hume *A Treatise of Human Nature,* Bk. I, pt. Ill, sect. xiv (Oxford, 1940), pp. 164-170; I. Kant, *Kritik der reinen Vemunft* (Leipzig, 1926), pp. 246-277.

type of explanation is clear in the mathematical theories of gravitation from the seventeenth century to our own day. The big difficulty, however, is that the problem of gravitation needs a much wider explanation than is afforded by mathematics; and history shows that thinkers have tried to reach a physical theory of gravitation—through mathematics.

The problem of gravitation in our day is complicated by two particular factors. First of all, there is the failure to distinguish between the kinds of explanation afforded by natural philosophy and mathematical physics. It is further complicated by a special problem "which seems to be equally lodged in both sciences, namely, the problem of space. It is this problem of space which has brought mathematicians to a reconsideration of their classical position, and it is this problem which challenges the traditional position of the Aristotelian philosopher of nature. Since the problem of gravitation involves a change of position in space—heavy bodies falling down and light bodies rising upward—the notion of " space " in some form or other is intricately bound up with the general problem. The background of every mathematical explanation is a " space " in which the equations are verified. What is the reality of space? How does it affect the falling and rising of bodies? Is mathematical space real? Is it the same as natural place? These questions must be answered in the course of explaining gravitation. The most suitable procedure is to treat the problem of space and gravitation in its historical development, considering principally the Aristotelian, Newtonian, and Einsteinian views. Throughout this discussion emphasis must be laid on the nature and role of " space " in gravitation and the distinct explanations afforded by natural philosophy and mathematical physics, their validity and relation one to the other.

I. Aristotelian Space

The background for the Aristotelian view of space is to be found in his predecessors. Parmenides, denying the possibility of plurality and movement, held that what underlies the illusory world of sense is a corporeal, spherical, continuous, eternal and immutable *plenum*.[8] Parmenides had formed a clear conception of space, as Burnet says,[4] but only to deny its reality. The absolute conception of space, the reality of which Parmenides denied, was taken over by Empedocles and filled compactly with bodily elements. Even though Empedocles insisted that all bodies move continually in the *plenum,* so as to leave no void, the *positions* which can be occupied by various bodies remain fixed and absolute.[0] It is as though space with its determined positions were something over and above the bodies which exist. When the atomists introduced the void they gave, it a reality equal to that of bodies.[6] Although the void was introduced by the atomists to explain the movement of bodies upward and downward, it was deficient in two respects. First, the void was supposed to be characterless,[7] but a characterless void could in no way influence a body to move upward rather than downward. Second, void itself moved in the void, allowing the vacuous bodies to move upward; but if void moves in void, then they cannot be the same characterless reality, nor can either void explain movement. " What is the cause of its movement? Not, surely, its voidness: for it is not the void only which is moved, but also the solid." [8] Yet in spite of these shortcomings it is clear that the Empedoclean and atomistic void came close to being a fixed framework with determined

* Cf. Diels, *Vorsok.,* 28 B.
* J. Burnet, *Early Greek Philosophy,* 4th ed. (London, 1945), p. 337.
" Cf. Diels, *Vorsok,* 31 B, frag. 17.
* Cf. Diels, *Doxog.,* p. 483; J. Burnet, *op. cit.,* p. 337.
''*Phys.,* IV, c. 8, 214b28-35.
[8] *De Coelo,* IV, c. 2, 309a27-28.

positions, a reality apart from the bodies which occupied the various positions.

Perhaps Plato was the first to have a clearly mathematical conception of space.[9] For him space, the receptacle of all things, is as real as the eternal ideas and more real than the bodies which occupy it. Plato conceives space as absolutely intelligible dimensions, independent of bodies, but capable of receiving bodies. For example, the dimensions of any room can be thought of independently of the room itself or of anything in it. It is as though *dimensions* were given a subsistence independent of mind and bodies, an absolute framework in which bodies can be conceived to exist. Whether one conceives geometrical figures or physical bodies there is necessarily a framework of dimensionality in which bodies succeed one another in the same place; the " place " of a body is none other than " that part of space which is actually occupied by a body." In other words, Plato conceives space as subsistent dimensionality " separated from any body." [10] That part of space which is occupied by the dimensions of a body is its " place "; and a " vacuum " is that part of space which is not occupied by any body.

Plato's conception of space as subsistent dimensionality is a very human and, therefore, common notion. Whenever we imagine any kind of magnitude whatever, it is set in a framework of unlimited dimensionality. For example, when we imagine a circle, there is room around it for any number of circles; when we see a mountain, we can imagine room for an infinite number of mountains next to it. But what is the reality of this " dimensionality " which is even a condition of our imagining anything physical? Plato made it a condition not only of imagination but of real existence. He projected a condition of human imagination into the physical world and

* Cf. Plato, *Timaeus,* 48 E-53 A.

[10] Cf. Aristotle, IV *Phys.,* 2, 209b5-33; St. Thomas, *In IV Phys.,* 3, n. 5; 6, n. 10; 7, n. 3; *In I de Coelo,* 9, n. 3.

made it a subsistent reality in itself—-as real as the eternal ideas which it reflects.

But Aristotle rightly objected that there can be no such extension existing apart from bodies.[11] " If there were an extension which were such as to exist independently and be permanent, there would be an infinity of place in the same thing." [12] Since all dimensions are infinitely divisible, each body would be existing in an infinite number of places at once.[1*] Dimensionality is the quantitative characteristic of bodies. Unless there i3 a body which is quantified, there can be no real dimensionality. In other words, dimensions such as length, distance, area, are quantities; these quantities are real provided there is a real body which has these dimensions. If absolute dimensionality really existed apart from the bodies which move about from one place to another, two bodies would always be occupying the same " place "—indeed, the moving body would always occupy an infinite number of places. Furthermore, Aristotle argues that " place " would be continually " changing " with the various bodies which occupied it; but strictly speaking, it is not place which changes but rather the bodies which move from place to place.[14]

The difficulty lies in the fact that we can conceive quantity apart from matter, apart from the real bodies which alone possess quantity. Just as we can think of circles, lines, and numbers apart from any physical body, so too we can think

[11] *Phys.,* IV, c. 4, 211bl3-29. Rosa thinks that here Aristotle is not attacking the Platonic view of a single space, distinguishable from the bodies that occupy it and move about in it, but the view that inside each container there is a self-subsistent interval specially connected with the container. (Cf. Ross, *Aristotle's Physics, ed. cit.,* p. 56, 572-3). However, it is difficult to see why the position attacked is not that of Plato, as St. Thomas seems to think (IV *Phys.,* lect. 6), especially as Aristotle actually presents the position, and Ross thinks it " curious " that he does not consider it *(ibid.,* p. 56).

[L] *Ibid.,* 211bl9-21.

[1S] Cf. St. Thomas, *In IV Phys.,* 6, n. 7.

[14] *Phys.,* IV, c. 4, 211b23-29.

of distance, volume, and dimensionality apart from any really existing body. But this imagined dimensionality is not a physical quantity; an imagined volume of 500 cubic centimeters is not an existent reality—-for nothing can be poured into it. This abstraction from physical bodies is not restricted to mathematical speculation, but is true of any consideration of quantities. Relations of length, distance, area, and the like are commonly discussed, and, indeed, independently of any particular body which actually has those quantities. Nevertheless, for any quantity to be *real* there must exist a physical body which is actually so quantified. We inevitably imagine a universal space, a general dimensionality over and above the bodies existing in the universe, but this in itself does not give reality to space. To have extra-mental reality, space or any other kind of extension must be a physical quantity of real bodies. This point is very important, but it can be brought out only by distinguishing this imaginative space from physical place and mathematical space.

Place, Natural and Otherwise

Aristotle rightly showed that Platonic space is of no value in explaining the movement of bodies. Why should one body go up rather than down? In one sense Platonic space is perfectly undifferentiated and characterless, as Plato says,[15] yet in another sense this space cannot be characterless, for otherwise why should a body be in one place rather than in another? Plato himself compares space to a winnowing basket which has holes of different sizes.[16] He attributes to his receptacle fixed positions suitable for the differently shaped elements.[17] Because Platonic space must be both differentiated

[15] " It must be called always the same; for it never departs at all from its own character; since it is always receiving all things, and never in any way whatsoever takes on any character." Plato, *Timaeus,* 50 B.

[18] *Ibid.,* 52 E-53 A.

" *Ibid.,* 57 B-58 C; also 63 A-E.

and undifferentiated, Plato is forced to admit that it is " very obscure and difficult to explain." [18]

Aristotle, who has little to say about space, insists that real motion can be explained only in relation to real place, a physical ambient for which a body has an innate preference. There are two essential features to the Aristotelian notion of place. It is first and foremost an environment, " the innermost boundary of what contains." [19] Secondarily, it is motionless, allowing bodies to move from one place to another. From the natural philosopher's point of view the environment is very important in explaining the movement and survival of bodies; the mathematician, abstracting from all qualitative considerations, is much more concerned with the immobility of place and the relations of distance.

Nothing in the universe is isolated and self-sufficient, for all natural phenomena manifest mutual dependencies. Since the first dependency of every body is upon its immediate environment, it must seek a suitable environment in which to thrive. This dependence upon a suitable place is more clearly evident in the higher categories of nature. A human being will adapt the environment to suit his needs or else move elsewhere. Birds fly south for the winter; different flora are found in different climates and conditions must be favorable to foster their growth. An analogous situation must explain the falling of bodies to the earth and stability thereon. It must be admitted that terrestrial stability is a decided advantage to the human body, trees, mountains, and minerals. These natural places, which are conducive to the very well-being of different natures, are environmental conditions toward which bodies necessarily move. In other words, different environments, or natural places must be acknowledged if motion is to be explained at all. Indeed locomotion is inexplicable without natural places toward which

[18] *Ibid.,* 49 A; also 51 B.
Phys., IV, c. 4, 212a20-21.

bodies determinate!}' move.[20] But the important point is that the place toward which a body naturally moves is essentially an environment suitable for the very survival and achievement of various natures.[21] When discussing bodies without consciousness and deliberate effort, we can only say that the active principle of nature automatically and spontaneously moves to that end.[22] To say that different kinds of bodies have different " natural places " is not to say that they have an absolute localization in space. A natural place is essentially a qualitative environment which is congenial to a particular nature and to which that nature spontaneously moves. Should the environment itself move, the body would not remain fixed in a point of space but would accompany or spontaneously seek out the nearest suitable environment.

Once Aristotle has shown that it is place which is the cause of motion, he tries to establish the absolute immobility of place. In this he is really trying to justify the absolute character of Platonic space. Plato had insisted that space is a dimensional framework over and above bodies. Aristotle rejects this because real dimensions must be the quantities of real bodies. But for Aristotle the whole universe is a plenum;[23] that is to say, physical bodies are contiguous to each other throughout the

[20] Cf. St. Thomas, *Sum. cont. Gent.,* Ill, cc. 22-23; *De pot.,* q. V, a. 5; *In IV Phys.,* 11.

[21] " Videmus enim quod unumquodque horum fertur in suum proprium locum quando non impeditur, grave quidem deorsum, leve autem sursum. Ex quo patet quod locus liabet quandam virtutem conservandi locatum: et propter hoc locatum tendit in suum locum desiderio suae conservationis. Non autem ex hoc ostenditur quod locus habeat virtutem attractivam, nisi sicut finis dicitur attrahere." St. Thomas, *In IV Phys.,* 1, n. 7.

[22] " Sic enim forma est principium motus localis, inquantum alicui corpori, secundum suam formam, debetur aliquis locus, in quem movetur ex vi suae formae tendentis in locum ilium, quam quia dat generans, dicitur esse motor." St. Thomas, *Sum. cont. Gent.,* Ill c. 23.

[23] *Phys.,* IV, cc. 7-9; see also J. de Tonqu<klec, *Questions de Cosmologie et de Physique chez Aristote et saint Thomas,* I. Le systeme du monde (Paris, 1950), pp. 7-71.

entire universe. Therefore, real dimensionality is established in the contiguity of bodies from the center to the circumference of the universe. Aristotle gives absolute meaning to the common expressions " up " and " down," so that a body which tends to fall " down " is really tending to an absolute center in the universe.[24] Therefore for Aristotle the earth must be immovable and the upward places must be spheres geometrically located around the earth as a center.[25] In other words, Aristotle's conception of determined spheres for the elementary bodies with the earth as an immovable center follows from the absolute immobility which he attributes to place.

But there are two difficulties involved in this part of Aristotle's doctrine: i) the validity of such an absolute localization of positions; ii) the spatialization of place.

While it is very easy to imagine an absolute dimensional framework in which the spheres of the heavens and the position of bodies are geometrically ordered, what actual meaning can such a conception have? When we see a row-boat moving across a lake, we see the relative positions of boat to shore. We say that the boat, is not moving if the relative positions remain unchanged. But can we say that even that relative order is absolutely immobile? If we are talking about an order or situs existing in reality, what basis is there for saying that it has absolute immobility? According to what framework is that order the same and immovable? To say that there exists an absolute matrix against which the immobility of positions has absolute physical significance is to assert something without justification. All we can really assert is that the relative positions *quoad nos* are the same and immovable. This is quite different from asserting an absolute immobility to place. When we speak of the universe as a whole, the absolute localization of positions is clearly impossible. Our notions have only

[14] *Phys.,* IV, c. 4; *De Coelo,* I II; cf. St. Thomas, *In IV Phys.,* 1, n. 7.
[15] *De Coelo,* I, c. 8, 277bl ff.; St. Thomas, *In II de Coelo,* lect. 6, nn. 5-6.

relative value *quoad nos.* This is all we are justified in meaning and this is all we need to mean.[20]

But the more important point is that physical place is not space. It is not to a position in space that natural bodies spontaneously move but to an environment. Heavy bodies do not fall to a point in the universe but to this earth. There is no logical justification for identifying natural place with fixed positions in the universe; in fact this identification is illogical, for we do not know what a fixed position is. Aristotle's cosmology as expounded in his *De Coelo et Mundo* very clearly spatializes natural place and reduces it to a fixed position in the universe. Jean Buridan is more realistic when he rejects this as pure imagination.[27] For him natural place has meaning only relative to a particular environment; thus the natural place of air is to be above water wherever it may be, and it is the nature of solids to fall below irrespective of +heir position in space.[28] In other words, actual experience shows that various bodies move to determined environments; it does not show that they move to mere positions in space.

The important point is that physical place is essentially a

[2]" " Est animadvertendum, quod punctum ad quod locus dicit ordinem et ex quo immobilitatem desumit, necesse est ut et ipsum sit quodammodo ftxum et immobile; at huius immobilitas non est pensanda simplieiter et absoluta, ut quidam etiam recentiores scholastici (v. g., Lorenzelli) tenere videntur; sed est solum secundum quid et relativa." A. M. Pirotta, *Bumma Philosophiae* (Turin,1936), II, 193, n. 294. Among contemporary scholastics who attribute absolute immobility to place we must mention P. Hoenen, who identifies place with an all-pervading and absolutely fixed *ether.* Cf. *Cosmologia,* 4th ed. (Rome, 1949), pp. 66-68; 460-467.

Buridan, *Quaestiones de Caelo et Mundo,* Lib. IV, q. 7, *ed. cit.,* pp. 266-7.

[ss] " Nee valet ilia imaginatio quod terra superior subdistracta inferiore terra, moveretur deorsum; quia si terra esset perforata usque ad centrum, non solum esset naturale quod terra proiecta in illud foramen descenderet ad centrum, imo etiam aqua ibi proiecta descenderet usque ad centrum, . . . quia hoc est naturalis inclinatio aquae quod sit sub aere; et aer etiam, ibi praeexistens, ascenderet naturaliter ad finem essendi supra aquam." Buridan, *Hid.,* p. 267, lines 4-20.

temporal conditions.[31] Tlie second characteristic arises from the nature of the human intellect, which can disregard matter, physical bodies, movement, and causality in a consideration of pure quantity. In other words, it is the abstractive character of an intellect radicated in a quantified, sentient body which conceives an all-pervading, homogeneous " space " separated from physical bodies.[82] It is this space which Plato objectivized, and it is this space which Kant, canonized. The point is that we must acknowledge a certain subjective condition of the human mind, a universal spatial izing condition, which makes geometry and even human experience of physical reality possible. But it is clear that this spatializing condition is not to be confused with real dimensions. Furthermore even if such an absolute space were to exist, it is clear that no undifferentiated space could account for the movement of bodies to one place rather than to another. It is only a physical environment, a qualitative circumstance, which can attract a nature spontaneously aiming at its proper self-enjoyment.

Strictly Mathematical Space

By a strictly mathematical space is meant the geometrical description of a phenomenon in reference to determined co-ordinates. Until the late nineteenth century Euclidean geometry was thought to be sufficient to describe all natural phenomena; and, indeed, it was generally accepted as the only geometry.[33] Coordinates chosen in astronomy were thought to have an

[81] St. Thomas, *In Boeth. de Trin.,* VI, 1-2; cf. *In II de Anima,* 5, nn. 283-285, lect. 12-13; see also *In III de Anima,* 8.

[Ea] A complete analysis of the psychological predispositions for knowing " space " has not yet been made, as far as we know. Partial attempts have been made by Poincare, *Science and Hypothesis, ed. cit.,* pp. 51-88, and by H. Weyl, *Philosophy of Mathematics and Natural Science* (Princeton, 1949), pp. 95-137.

[.3] On the history of non-Euclidean geometries, cf. A. Whitehead, *Essays in Science and Philosophy, ed. cit.,* pp. 177-226.

absolute value so that all movements could be described adequately in relation to them. Euclidean geometry so used was an identification of imaginative with purely mathematical space. While it is true that all geometry is ultimately projected against the background of imaginative space, it would be an error to identify them. In practical mathematics the principal aim is to determine positions by measurements and to describe them in equations valid in some coordinate system. As soon as it is a question of measurement, then more than imaginative space is involved. What is actually involved is a space constructed in accord with our measurements. This space is utilized in what Einstein calls " practical geometry "; and " its affirmations rest essentially on induction from experience, but not on logical inferences only." [34]

All measurements are made relative to fixed frames of reference, or at least to frames which can be assumed as fixed. In classical mechanics all inertial systems constructed with Galilean coordinates were simply transformable one into the other. An inertial system, as has been shown in the last chapter, presupposes an absolute space in which the Newtonian principle of inertia has meaning. It was thought that the propagation of light waves through interstellar space demanded a substantial carrier of some kind—an " ether absolutely at rest." But all experimental attempts, for example, those of A. A. Michelson and E. W. Morley, to measure the absolute motion of the earth with respect to the ether had failed. The failure to determine an absolute space led to a critical examination of the meaning of space and time in mathematics. This work, begun by Henri Poincare, H. A. Lorentz, G. F. Fitzgerald and others, was synthesized in 1905 by Albert Einstein in his restricted theory

"* Einstein, " Geometry and Experience," an address given to the Prussian Academy of Sciences in Berlin, Jan. 27, 1921, in *Sidelights on Relativity* (London, 1922), p. 32.

of relativity, which emphasized the special character of mathematical space as distinct from imaginative space.

The peculiar characteristic of mathematical space is that it is constructed from our measures. Mathematical measurements depend upon the position and condition of the observer; since the mathematician himself is situated in a particular place in the universe and makes his measurements at a particular time, his measurements are necessarily relative to himself as a physical " event." Classical mechanics, which assumed an absolute space or ether to justify inertial motions, thought that a mathematical description of an event for one observer would serve equally for another observer through a process of simple transformation. This is to say, the straight line *PQ* for observer A would be described in co-ordinate system *x, y, z, t;* and the same straight line would be described for observer B, moving uniformly along the *x* axis, in co-ordinate system *x', y', z, t'*. Thus the description for the square of the line element *PQ* remains invariant for both systems as $(x_2 - xi)^2 + (y_2 - yi)^2 + (22 - Zi)^2$, $ordx^2$ -f $dy^2 + dz^2$. But this assumes that each observer ascribes the same values *to* the other's lengths and times as to his own, a thesis which cannot be supported unless there be an absolute space which can be determined. The special theory of relativity rejects absolute motion, that is, the possibility of measuring motion in relation to absolute space. Following Lorentz, Einstein insists that all measurements of space and time are strictly relative to the observer. Assuming that the velocity of light is constant for any given observer, he shows that no observer can detect his own movement, but another observer moving uniformly and rectili- nearlv with respect to it would detect a slight " contraction " of A's length in the direction of motion. Thus while A cannot detect any contraction of his own measuring rods, B can; and conversely. Therefore, Einstein concludes, a simple transformation cannot be made between A's system and B's, but account must be taken of the relative difference in measurement. The

equivalence of these two systems is accomplished by a new transformation, known as the Lorentz transformation, in which

$$X = \frac{x - ut}{\sqrt{1 - \frac{u^2}{c^2}}}, \quad y' = y, z' = z, t' = \frac{t - \frac{u}{c^2}x}{\sqrt{1 - \frac{u^2}{c^2}}}$$

where c = the velocity of light *in vacuo*. According to this transformation the interval between P and Q, observed by two observers moving in uniform rectilinear motion, remains invariant in the description $dx^2 + dy^2 + dz^2 - c^2dt^2$, since the discrepancy of the two observers is rectified in the subtractive term. By means of the constant velocity of light for any given observer Einstein explained the Fitzgerald "contraction" and the Lorentz transformation, both of which were offered to explain the failure of the Michelson-Morley experiment to determine the absolute velocity of the earth relative to a stationary ether.

The equivalence of these two systems by means of the Lorentz transformation is reallv a unification of two different co-ordinate systems, as Minkowski later showed. The result is a kind of "curvature," which merely means that the relations between the mutual distances of the points are different from the relations which obtain in Euclidean geometry. As Sir Edmund Whittaker points out,

> Curvature (in the mathematical sense) has nothing to do with the *shape* of the space—whether it is bent or not—but is defined solely by the metric, that is to say, the way in which "distance" is defined. It is not the space that is curved, but the geometry of the space.[35]

Furthermore the event PQ which is described in either inertial system embodies a curvature. That is to say, time is not considered as an independent co-ordinate, but as an element intrinsically affecting the measurement of space itself. Thus in the

[35] E. Whittaker, *From Euclid to Eddington, ed. cit.,* p. 40.

description of relativity it is not the *distance* between points *P* and *Q* which is specified, but the *interval* between two events emerging in time. In the four-dimensional continuum of spacetime every event is described as emergent in time; when this emergence is designated by co-ordinates, the matrix is a set of Gaussian curves. Thus in the extended theory of 1916 Einstein presented the exact formulation of the general principle of relativity as " All Gaussian co-ordinate systems are essentially equivalent for the formulation of the general laws of nature." [38]

The important point to notice is that geometric space is constructed from measurements. It is not a question of the real space of the universe, but of the geometric space which must be used by us to describe measurents accurately. When dealing with velocities considerably less than that of light, the discrepancy of systems is not sufficiently great to give a "curvature " to geometric space. The essential point is that geometric space is not identical with imaginative space; rather it is constructed either from axioms in " axiomatic geometry," or from measurements in " practical geometry." [37] But it is clear from what has been said that all systems of geometry are projected against the background of homogeneous imaginative space.

It is evident, then, that neither imaginative nor mathematical space, strictly so-called, constitute the space of the universe, for real space is the objective dimensionality of a body or of the sum total of all bodies. But we have no means of determining the real nature of universal space, for all our statements about it are relative to our own position within the universe. Hence our statements about the " immobility " of real space have no absolute meaning. Furthermore even assuming that an absolute immobility could be ascribed to space, this space would have no value in explaining the movement of bodies to one place

[36] Einstein, *The Theory of Relativity* (London, 1924), p. 97.

[17] Cf. Einstein, " Geometry and Experience," in *Sidelights on Relativity,* pp. 27-56.

rather than to another. An undifferentiated " space " cannot account for the difference of movement. It is place rather than space which yields an explanation of locomotion. Physical place, being a qualitative environment, can account for the spontaneous movement of a body to one place rather than to another, for it is within the intentionality of natures to seek a suitable environment in which to thrive and to reach fulfillment. While it is true that place must manifest a certain " immobility," there is no need to think of it as absolute. All that is evident in experience is the relative immobility of natural place; and this is all that is required to explain the movements given in human experience.

The difference between space and natural place has been pointed out in order to show that it is to place as such that natural bodies move. Nature as an active principle is a source of spontaneous movement, of movement which aims at some realization of fulfillment for the being itself. The first requisite for natural bodies is that they be in a suitable habitat; thus if they are not, nature necessarily moves toward an environment conducive to conservation and " self-enjoyment." It is on this basis of natural spontaneity and the final causality of place that the Aristotelian and Thomistic tradition explains gravitation. However, the more popular explanation of gravitation is the mechanical theory of attraction.

II. Newtonian Attraction

A gravitational theory of mechanical attraction is a very simple explanation of the phenomenon of falling bodies. It is very satisfying to the imagination, especially to an imagination which has grown accustomed to accept mechanical explanation. For more than two hundred years students of physics have been taught that bodies fall to the earth because of the gravitational " pull " of the earth; they have been taught to believe that the

planets are retained in tlieir orbits because of inertia and the mutual attractions of masses scattered throughout the universe. While this explanation is very satisfying to the imagination, it leaves much to be desired intellectually and experimentally.

Of course, in the present context " attraction " is used in the sense of an efficient cause. Scholastic philosophy also used the term to signify the causality exerted by a desirable good, as when a boy is attracted by candy and cakes. But in the order of final causality the good is said to " draw " or to " attract " only in a metaphorical sense.[38] In the present discussion the term attraction is meant to signify efficient causality, a pulling force, which draws other bodies as a horse pulls a cart.

IIistorical Background

Aristotle and St. Thomas considered briefly the possibility of a mechanical explanation of gravitation, both attraction of bodies by the earth and a forcing down of bodies by a whirling force.[89] But an explanation of gravitation by external forces of either the pushing or pulling kind would destroy the whole concept of nature as an intrinsic principle of the body's own movement, for " nature " is not a power of moving other bodies but a spontaneous source of a body's own proper movement. Furthermore, Aristotle argued that one or the other mechanical explanation could not account for the evident accelerated movement of light bodies upward and heavy bodies downward; each explanation might conceivably explain one type of acceleration, but could not explain both together.

Already in the thirteenth century, however, there were some

[as] " Attractio autem non est propria motio, quia motio non est transitus aliquis, ilia autem attractio solum est convenientia et sympathia unius ad alterum, ut trahatur ab illo, quod non nisi translative dicitur motio." Joannis a S. Thoma, *Curs. Phil., Phil. Nat.,* I. P., Q.XIII, a. 11, *ed cit.,* II, 276b.

[3"] Arist., *De Coelo,* 1, c. 8, 277b 1-8; St. Thomas, *In I de Coelo,* 18, nn. 1-4; also *In II de Coelo,* 23, n. 4.

who attributed more than mere final causality to Ihe natural place of bodies. St. Bonaventure believed that over and above spontaneity and the final causality of place one had to attribute an attracting force to natural place and an expelling force to unnatural place.[40] Roger Bacon developed a rather complete " field " theory to account for gravitation. He maintained that besides the generator of bodies and the final causality of place, all bodies and the whole medium are permeated by an immaterial power derived from the heavenly bodies. Neither the natural form of bodies nor the suitability of place, he thought, are sufficient to account for movement; there is needed a *virtus immaterialis,* which fills all space and is concentrated more intensely in the natural place.[41] For Bacon the natural place of a body exercises not only final causality but efficient causality as well.[42] Thus in Bacon's view gravity and levity are diffused immaterial forces which, although derived from the heavenly bodies, are concentrated in various natural places.[43]

[40] " Dicendum quod ad motum gravis non sufficit solummodo gravitas sive qualitas propria, immo concurrit virtus loci attrahentis et virtus loci expellentis et virtus corporis quanti, praeter ilia dua moventia, quae ponit Philosophus, soil, generans grave et leve, et removens prohibens." *In II Sent.* 14, p. 1, a. 3, q. 2; also Richard of Mediavilla, *In II Sent.* 14, a. 2, q. 4 (Brescia, 1591).

[41] " . . . movetur a principio intrinseco, scil. a forma immateriali, quae non est actus ipsius materiae gravis, unde non movetur a forma materiali, quae est actus suae materiae, quia ilia forma non est aliquid praeter hoc, quod sit actus materiae, immo est purus actus materiae, et nulla talis forma sufficit ad hoc, quod aliquid de se movetur; sed movetur a forma immateriali quam participat, quae non est actus materiae ipsius, sed virtus ipsa caelestis minus complete ab ipso gravi participata, a loco autem deorsum magis complete." *Questiones supra libros 8 Physicorum, Lib. Till, Opera hactenus intdita,* fasc. XIII (Oxford, 1935), pp. 398-9; cf. pp. 396- 410; also *Quaestiones supra libros / Physicorum ibid.,* fac. VIII (Oxford, 1928), p. 173 ff,; *Communia Naturalium,* I p. Ill, d. 2, c. 3; *ibid.,* fasc. Ill (Oxford, 1911), pp. 204-5.

[42] " finis non movet secundum veritatem, sed metaphorice." However, " locus est causa motus in genere finis et etiam efficientis excitantis." *Ibid.,* fac. XIII, p. 409.

*' " Dicendum quod gravitas et levitas non solum attenduntur a parte mobilis, sed etiam a parte medii, quia quantum attendit magis ad inferiorem

At least as early as the fourteenth century some conceived place as a total efficient cause of gravitation. Buridan mentions this opinion of *aliqui,* who say that " *locus est causa movens ipsum, grave per modum attractionis, sicut magnes attrahit fer- rum."* [44] He attacks this opinion as contrary to experience, " because if iron is near a magnet, it immediately starts moving more quickly than if it were farther removed; but this is not the case of heavy bodies with regard to their natural place." [45]

The revival of Platonism in the fifteenth and sixteenth centuries popularized the theory that all similar bodies tend to congregate. Copernicus himself proposed this explanation to account for the rotundity of bodies and spheres, as well as for gravitation.[46] This Platonic and Pythagorean theory of gravitation was generally employed by Copernicans who rejected the absolute space of Aristotle.[47]

However at this time many experiments were performed with the magnet. In 1600 Sir William Gilbert of Colchester (1546- 1603), personal physician to Queen Elizabeth, published his influential work *De Magnete,* in which he suggests that gravitation is nothing but the attraction of the great magnet, the Earth.[48] The Englishman, Nicholas Hill, whose *Philosophia Epicurea* appeared in 1601, equated magnetic attraction and

partem medii, tanto magis acquirit de ilia forma diffusa a centro ad circumferentiam per medium, quae continuat partes mobilis et est virtus immaterialis, qua unumquodque fertur ad locum." *Communia Naturalium, loo. cit.*. The Pseudo-Grossetete and John Baconthorp also follow this teaching of Roger Bacon. Cf. A. Maier, *An der Qrenze, ed. cit.,* pp. 181-2.

[41] Buridan, *Quaestiones de Caelo,* II, q. 12, *ed. cit.,* p. 177; cf. p. 179 and IV, q. 2, pp. 248-50.

[45] *Ibid.,* 11, q. 12, p. 179, lines 5-7: "quia si ferrum sit propinquius magneti, statim incipiet velocius moveri quam si esset remotius; sed non est ita de gravi respectu sui loci naturalis."

[*] Copernici, *De Revolutione Orbium Caelestium,* lib. 1, cap. 9 (Thorn, 1873), pp. 24-25.

[47] Cf. A. Maier, *An der Grenze, ed. cit.,* pp. 170-173.

[48] W. Gilbert, *On the Magnet, magnetic bodies also, and on the great magnet the earth* (London, 1900), cf. especially I, c. 17, pp. 41-43; VI, c. 4-5, pp. 225-230.

gravitational pull; in proposition 206 he said that " the inclination of things to the earth is nothing other than magnetic attraction *(adhaerentia)*and he maintained that this attraction is exerted reciprocally.[49] The revival of Epicurean atomism by Marke Ridley, Sebastian Basso, Daniel Sennert, and Magnen strongly fostered an attractional theory of gravitation similar to magnet attraction.[50] Pierre Gassendi (1592-1642) enunciated the prevailing atomist theory of gravitation in his popular *Animadversiones in Decimum Librum Diogenis Laertii:* " Gravitas non tam videatur qualitas ipsis gravibus inexsistens, quam vis impressa ex attractione magnetice facta ab ipsa Tellure." [51] He insisted that gravity is not a property of bodies, but rather a force externally impressed upon them by the earth.[62]

However much Descartes favored a mechanical explanation of motion he could not accept the theory of magnetic attraction, for this attraction was explained by the emission of very small and subtle particles which acted like fish hooks pulling bodies to the magnet.[53] Since every extension must be infinitely divisible, Descartes denied the possibility of atomism. Descartes rejected every theory of gravitation which made gravity an innate tendency of bodies, or which explained it by the attraction of the earth.[54] To him the prevailing opinion of " attraction," " sympathy," and " antipathy " employed occult forces which

*" Cf. G. McColley, "Nicholas Hill and the Philosophia Epicurea," in *Annals of Science,* IV (1939), 390-405. Quotation cited from p. 396, note 46; cf. also prop. 438, cited on p, 397, note 51.

r'° Cf. M. Boas, " The Establishment of the Mechanical Philosophy," in *Osiris,* X (1952), 412-541.

31 Gassendi, *Animadversiones,* 3rd ed. (Lyons, 1675), I, 167a. See also his *Philosophiae Epicuri Syntagma* (Lyons, 1675), II, 380b-384a.

t2 *Animadversiones, ed. cit.,* 245a; cf. 243b-255b.

63 Cf. Gassendi, *ibid.,* I, 245b ff.

54 " Je ne eroy point non plus que les corps pesans descedent par quelque *qualite ree'lle,* nommee pesanteur, telle que les philosophes l'imaginent, ny aussi par quelque attraction de la terre." Letter LXI, Automne 1635, *Oeuvres* I, 324.

were not conformable to strictly mechanical laws.[55] Descartes' friend, Isaac Beeckman, suggested a possible solution in his *Journal* of 1604-1634. He maintained that throughout the entire universe there is an " ether or subtle matter which is always in motion this, he said, accounts for the gravity of bodies.[56] Descartes constructed an elaborate theory of movement by means of this subtle revolving matter, which he called vortices. The ether which permeates the entire universe constitutes a perpetual whirlpool with various centers of revolution.[57] Bodies, themselves devoid of motion, are impelled by the force of the vortex, so that heavier bodies are forced to the center, while lighter bodies are carried to the circumference. Thus gravity is nothing but the impact of vortex motion forcing heavy bodies to the earth.[58] Descartes took issue with Galileo for assuming gravity to be innate in bodies and for saying nothing about its nature.[59]

Descartes' philosophy became very popular in France through

[r]3 Cf. *Principia Philosophiae,* IV, pp. 184-7.

"“Beeckman, *Journal,* I, 25-20 (1013-14); 381-2 (1626-7); cf. M, Boas, *art. cit.,* p. 434 ff. For a good study of Descartes' indebtedness to Beeckman, cf. A. Kayre, *Etudes Galileenes,* II, " La loi de la chute des corps: Descartes et Galilee" (Paris, 1939), 99-119.

SI Cf. *Prin. Phil.,* P. Ill, *ed. cit.,* pp. 80-202. Compare this with the early Atomist doctrine presented by Aristotle *(De Coelo,* I, c.. 8, 277b 1-8) and Theophrastus (Diels, *Doxog.,* pp. 142-3).

63 Cf. *Prin. Philo.,* P. IV, art. 20-27. The French translation (1647) undertaken by Abbe Claude Picot expresses Descartes' view very clearly: " Toute la pesanteur de ce corps eonsiste en ce que le reste de la matifere subtile qui est en cette portion d'air, a plus de, force a sMloigner du centre de la Terre, que le reste de la matiere terrcstre qui le compose." *Prin.,* P. IV, art. 24, *Oeuvres, IX,* p. 212. In his letter to Claude Picot Descartes says, "I have known none of them (Aristotle, Plato and the Schools) who did not presuppose weight in terrestrial bodies, but although experiment proves to us very clearly that the bodies we call weighty descend toward the centre of the earth, we do not for all that know the nature of what is called gravity, that is, the reason or principle which causes bodies to descend thus, and we must derive it from elsewhere." English trans. by Haldane and Ross, *The Philosophical* IForfcs *of Descartes,* I, 207 (Cambridge, 1911).

58 Letter XCI to Mersenne, Epistolae, Amsterdam 1714, t. 11, pp. 276- 287. Descartes goes so far as to say about Galileo, " in eius libris nihil

the efforts of Mersenne, Arnauld, and Rohault.[60] Jacques Rohault's *Traite de Physique* became a very widely used textbook for students of physics.[61] Cartesian mechanics was introduced into England by A. Digby (1603-1665); and it flourished at the University of Cambridg'e even after the time of Newton.[62] It is interesting to note that the Cartesian system became known as the "mechanical" philosophy.

The supporters of an attractional, or " non-mechanical " theory of gravitation strongly opposed the Cartesian system of vortices. However, little advance was made until Newton published his *Principia Mathematica* in 1687 in which he commonly employed the term *attractio* in explaining universal gravitation. Although Newton carefully avoided any explanation of the " cause of gravity," his use of the term *attraction* immediately suggested the idea of a force similar to magnetism; and readers of the first edition inevitably took it as a defense of the prevailing attractional theory.[63] For this reason Leibniz strongly attacked Newtonian attraction as " a senseless occult quality, which is so very occult that, it can never be cleared up, even though a Spirit, not to say God Himself, were endeavoring to explain it." [64] The popularity of the *Principia* in England was

video, quod ipsi invideam, aut fere nihil, quod promeo vellem agnoscere." *Ibid.,* p. 281.

0 Cf. P. Boutroux, " L'enseignement de la micanique en France au XVII« sifccle," in *Isis* IV (1922), 276-294.

1 Cf. G. Sarton, " The Study of Early Scientific Textbooks," in *Isis,* XXXVIII (1947-8), 137-148.

"2 Cf. Cajori's notes in his edition of the *Principia* (Berkeley, 1947), pp. 629-632.

3 Readers of the first edition had justification for assuming that Newton intended to support the attractional theory. Newton's phrases suggest it. He savs (Book 1, Prop. EX): "If two bodies . . . attracting each other with forces inversely proportional to the square of their distance"; (Book I, Prop. LXIX) "the absolute forces of the attracting bodies"; (Book I, Prop. LXXII) "the attraction of one corpuscle towards the several particles of one sphere"; (Book I, Prop. LXXV) "the attraction of every particle is inversely as the square of its distance from the centre of the attracting sphere," etc.

4 Leibniz letter to Hartsoeker, Feb. 10, 1711, in *Phil. Schriften,* ed.

largely due to Newton's followers, Roger Cotes, Samuel Clarke, Richard Bentley, and others, rather than to any effort on Newton's part. These followers defended Newtonian physics as a refutation of " mechanical philosophy." In the famous preface to the second edition of the *Principia* (1713), Cotes refutes the Cartesian system of vortices and defends the mutual attraction of bodies throughout space, since the ultimate explanation of gravitation cannot be " mechanical." [65] Samuel Clarke, considered to have been the leading English metaphysician of his day, defended Newtonian philosophy for his bachelor's degree at Cambridge (Caius) in 1695. Two years later he made a new Latin translation of Rohault's *Traite de Physique* to which he appended Newtonian notes which virtually amounted to a refutation of the Cartesian text; gravitation is explained as attraction at a distance as against the pushing of bodies by vortices. The Rohault-Clarke treatise became the outstanding scientific textbook in England and America, so that many generations of English and American students (at Yale until 1743) learned Newtonianism in a Cartesian textbook.[66] Voltaire popularized Newtonianism in France through his *Elements de la Philosophie de Newton* (1738); this popular and witty treatise inspired many of the *Encyclopedic* (1751-1780) and did much to overthrow the Cartesian theory in France.[87]

Gerhardt (Berlin, 1887), III, 519; see also his " Antibarbarus physicus pro philosophia reali contra renovationes qualitatum scholasticarum et intelligentiarum chimaericarum," *Phil. Schriften,* VII, pp. 337 ff: Although Christian Huygens accepted the law of the inverse square, he rejected what he supposed to be Newton's theory of attraction and continued his adhesion to the tenet of Descartes, cf. Discourse de la cause de la pesanteur in his *Traits de la lumiire* (Leyden, 1690), pp. 125-180.

"[5] Newton's *Principia,* ed. Cajori, xx-xxxiii; cf. Cajori's notes, pp. 632- 637.

•* Cf. G. Sarton, " The Study of Early Scientific Textbooks," in *Isis,* XXXVIII (1947-8), 137-148.

[81] Cf. H. Butterfield, *op. cit.,* pp. 124-158. Voltaire was refused a license to print his book in France by the Chancellor, Henri d' Agriesseau, a Cartesian. Writing to his old friend, Thiriot, Voltaire says, " Perhaps I

Thus the Newtonian theory of " attraction " was promulgated by men, many of them religiously inclined, who wished to overthrow the Cartesian system, considered by many as " atheistic," and to replace it with a " non-mechanical " philosophy. When Newtonian philosophy gained ground in Europe, it was the opinion of his admirers rather than that of Newton himself which became prevalent. Newton's personal opinion was very different from any magnetic-like attraction which caused bodies to fall to the ground. It is almost ironical that the popular theory should have become known as " Newtonian attraction."

Newtons Personal Explanation

Newton was very reticent about expressing his views on the cause of gravitation. He insisted that his *Principia* was designed " only to give a mathematical notion of those forces, without considering their physical causes and seats."[68] In the general scholium to his great work he plainly states,

> Hitherto I have not been able to discover the cause of those properties of gravity from phenomena, and 1 frame no hypotheses; for whatever is not deduced from the phenomena is to be called an hypothesis; and hypotheses, whether metaphysical or physical, whether of occult qualities or mechanical, have no place in experimental philosophy.[69]

Newton was induced to take this stand in order to avoid becoming involved in disagreeable controversies, which he always detested.[70] He maintained that his mathematical principles are

should be obliged to him. I dealt with the philosophy of Descartes as Descartes dealt with that of Aristotle ... I would have gained nothing but new enemies." (quoted by Sarton, *art. cit.,* p. 145). The work was first printed in Amsterdam in 1738.

[08] *Principia,* Def. VIII, ed. Cajori, p. 5; also Bk. I, sect. xi (p. 164); Scholium to sect. xi (p. 192) ; *System of the World,* n. 2, p. 550; *Optics,* Bk. II and III.

[e'] Ed. Cajori, p. 547.

[70] Cf. Cajori's analysis of the famous phrase, *ibid.,* note 55, pp. 671-676; also Snow, *Matter and Gravity in Newton's Physical Philosophy* (London, 1926).

based upon observable phenomena and are not the result of metaphysical speculation, such as was the system of Descartes. Indeed he insisted that his laws of gravitation are independent of any philosophical hypotheses.

> What I call attraction may be performed by impulse, or by some other means unknown to me. I use that word here to signify only in general any force by which bodies tend towards one other, whatsoever be the cause.[71]

Although Newton refrained from declaring clearly the cause of gravitation for lack of experimental evidence, he pursued such an investigation throughout his whole life. About eight years before the publication of the *Principia* Newton wrote some of his suspicions to Robert Boyle, since he was asked to do so.[72] In this youthful period Newton believed that forces such as cohesion, repulsion, fermentation, and gravity might be explained by " an aethereal substance, capable of contraction and dilatation, strongly elastic, and, in a word, much like air in all respects, but far more subtile." [73] This " aethereal substance " is, in fact, similar to Boyle's own use of *effluvium,* or " etherical spirit " as an attracting or repelling force emitted by bodies.[74] The *effluvium,* which was commonly discussed by Gilbert, Gassendi, Boyle, and other adherents of the " corpuscular philosophy," was never clearly defined but was generally conceived as a subtle material substance, either as an elastic ether or as subtle emanations.

In later years Newton seems to have thought of gravity as due to a more immaterial cause. He certainly did not think of

[71] Newton, *Optics,* 3rd ed. (London, 1721), Q. 31, p. 351.

[71] Letter to Boyle, Feb. 28, 1678/9, first printed in *Life of Robert Boyle* by Thomas Bireh, *Works of Robert Boyle* (London, 1744), I, 70-73.

[73] *Ibid.*. p. 70.

Cf. Boyle, " Of the Strange Subtility of Effluviums," *Works,* pp. 38-42; 52-3; "Of the Great Efficacy of Effluviums," pp. 18-19, 32-33; "Of the Determinate Nature of Effluviums," pp. 21, 57; "The General History of the Air," p. 641.

gravity as a force inherent in bodies which attracted other masses at a distance. In a letter to Bentley, who was then preparing a course of sermons against atheism,[75] Newton wrote:

> You sometimes speak of gravity as essential and inherent to matter. Pray, do not ascribe that notion to me; for the cause of gravity is what I do not pretend to know, and therefore would take more time to consider it.[76]

In another letter he says:

> That gravity should be innate, inherent, and essential to matter, so that one body may act upon another at a distance through a vacuum, without the mediation of anything else, by and through which their action and force may be conveyed from one to another, is to me so great an absurdity, that I believe no man, who has in philosophical matters a competent faculty of thinking, can ever fall into it. *Gravity must be caused by an agent acting constantly according to certain laws; but whether this agent be material or immaterial,* I have left to the consideration of my readers.[77]

It is interesting to note that even at this time, Newton allowed for the possibility of an *immaterial* agent to account for gravitation.

In the general scholium added to the second edition of the *Principia* (1713) Newton devotes considerable space to showing rhe immediate dependence of the universe upon Divine Providence. All things and all motions fall under the " dominion " of God Who is eternal and everywhere present. " He endures forever, and is everywhere present; and by existing always and everywhere, *he constitutes duration and space."*[78] Absolute space is not God,[70] but it is the " sensorium of God." In the

[78] Brewster, *Life of Sir Isaac Newton* (London, n. d.), pp. 256-261.

[76] Letter to Bentley, 1692/3, in Edleston, *Correspondence of Sir Isaac Newton and Professor Cotes* (London, 1850), p. 159.

[77] *Ibid.* (emphasis mine). Note also *Principia*, Bk. I, Prop. LXIX, scholium: "whether corporeal or incorporeal," *ed. cit.,* p. 192.

[78] *Principia,* ed. Cajori, p. 545 (emphasis mine).

[78] *Ibid.;* and *Optics* (London, 1721), Q. 28.

thirty-first query, which he appended to the second edition of the *Optics* (1717), Newton insisted that " Particles have not only a *Vis inertiae,* accompanied with such passive Laws of Motion as naturally result from that Force, hut also that they are moved by certain active Principles, such as that of Gravity." [80] In other words, Newton conceives bodies to be purely passive, incapable of accounting for their motion or the motion of other bodies. Therefore, some active principle is necessary for putting bodies into motion and for conserving motion already existing.[81]

A further knowledge of Newton's notion of universal principles of motion may be gained from a consideration of his forerunners in philosophy, principally J acob Boehme and Henry More. Brewster records that Newton was a constant reader and admirer of Boehme, copying many a page from this famous Protestant mystic.[82] Boehme (1575-1624) tried to solve the problem of man's union with God. Since man is a finite being and God, infinite and removed in His heaven, how could man have experience of Him? Boehme answered that God is not removed from this universe but actually constitutes the " soul of nature." Man finds God within himself, for man is a part of the whole of nature and the drama enacted within his own soul merely reflects the drama of the divine essence in the universe.[83]

Henry More, who reintroduced Platonism into Cambridge and directed attention to Boehme, directly influenced Newton's mystical philosophy.[84] For More the whole universe is permeated by spirit, the " immaterial cause " of all motion, co-

[*°] *Optics,* Q. 31, *ed. cit.,* p. 397.

[81] Cf. Boas, *art. cit.,* pp. 483-520.

[82] Brewster, *Memoirs of Sir Isaac Newton,* 2nd. ed. (Edinburgh, 1860), II, 371.

[83] Boehme, *Morgenrote im Aufgang,* 1612; *Drei Prinzipien gottlichen Wesens.* Cf. A. Koyre, *La Philosophie de J. Boehme* (Paris, 1929).

[84] Cf. Snow, *op. cit.,* p. 192 ff.

hesion, attraction and repulsion. This spirit is not God Himself; but it is the *anima mundi*.[85] The spiritual substance, which penetrates matter and is the true cause of motion, More identifies with *space,* which he calls the " extension of God, His ubiquity, and His sensorium." Following Boehme, More insists that space is a spiritual and divine reality, representing to us the divine essence. Prof. Snow says,

> It is in the law of gravitation through the action at a distance which is a mathematical expression of an empirical fact—which is not by material impact nor action through a material medium—that Newton found a mathematical and empirical confirmation of More's Neo- Platonic philosophy.[86]

Therefore for Newton this gravitational action is not " mechanical," that is, it is not produced by Cartesian impact or material effluvia, but is the action of God operating through space, His " senorium." Like More, Newton attacked the "atheism" of Descartes' doctrine and insisted that although bodies move *as though* based upon mechanical laws, the ultimate cause of movement cannot be mechanical.[87] Referring to the *Principia,* Newton said in a letter to Richard Bentley (Dec. 10, 1692/3),

> When I wrote my treatise about our system, I had an eye on such principles as might work with considering men for the belief of a Deity; and nothing can rejoice me more than to find it useful for that purpose.[88]

Concluding his study on Newton's personal philosophy, Prof. Snow says,

> The action, as it is described in the law of gravitation, is *direct* and *immediate* in the form of immaterial etheral emanations of spiritual forces through absolute space as its medium, which space is in itself

[85] More, *Immortality of the Soul,* preface; cf. also *Enchiridion Meta- physicum,* chap. 28.

[89] Snow, *op. cit.,* p. 203.

[87] Newton, *Principi,* General Scholium, *ed. cit.,* p. 546.

[BS] Quoted by Cajori, *Principia,* n. 52, p. 669.

an immaterial " sensorium of God " . . . God becomes the " Soul of the World," being immediately substantially present everywhere— although Newton tried to guard himself against Pantheism.[89]

For Newton, then, gravitation is not to be explained by magnetic-like forces inherent in bodies which " attract," but by the direct action of God operating through space. Although the laws of gravitation may be expressed as though bodies mutually attract one another in the inverse proportion of their distance, the cause of gravily, Newton held, cannot be attraction. The theory, therefore, which has been promulgated as Newtonian attraction does not represent the personal philosophy of Newton but of his successors who seized it to combat the " atheism " of Cartesian philosophy or who accepted the *prima facie* meaning of the *Principia.*

Evaluation of Newtonian Attraction

As late as the nineteenth century the theory of gravitational attraction was defended as a " non-mechanical philosophy "; inexplicable forces which attract bodies at a distance were thought to be more conducive to theism and religion.[90] It is clear, however, that from an Aristotelian point of view both Cartesian impulsion and Newtonian attraction are *mechanical* explanations of gravitation. Whether the action be exerted at a distance or through a material medium does not affect the question. The immediate point concerns the agency responsible for a body's movement. In Newtonian attraction two bodies are said to attract each other mutually, but the actual movement of any one of them is *due* to the " attraction " of the other. Thus A's motion is due to B's pull, and B's motion is due to A's pull;

[8]" Snow, *op. cit.,* pp. 208-9.

[9]"E.g., Andrea de Guevara v Basoazabal, *Institutionum Elementarium Philosophiae* (Valentia, 1825). Ill, 154-5. This work was the common textbook in Spanish seminaries during the first half of the 19th century; cf. Spanish *Enciclopedia* (Barcelona, 1925), XXVII, 207a.

the pull ot' the earth is said to account for the motion of falling bodies. Aristotelian philosophy considers any universal theory which endeavors to explain all motion by an external agency mechanical in the strict sense of the term. Arisrolelianism acknowledges a natural spontaneity within bodies to account for their own movement relative to the environment; mechanics in the strict sense of the term refers all motion to an external agency. Thus the first point to be made is that Newtonian attraction, as it is commonly understood, is really a mechanical explanation of gravitation.

Furthermore, *Newtonian attraction has never been proved;* that is to say, it has never been proved that bodies fall to the earth because of " attraction " or that planets are retained in their orbits because of solar attraction. The very fact that Newton himself did not believe in a force of this kind clearly indicates that he did not *prove* the existence of such a force. Obviously if Newton did not believe that gravitation could be explained philosophically by the " mutual attraction " of bodies according to the law of the inverse square of the distance, he did not prove that bodies fall because of the earth's " attraction." All Newton wanted to show was that if such an attraction be assumed, then a universal law of gravitation could be formulated to describe all known motions. This is merely a convenient hypothesis upon which to formulate mathematical laws. The validity of a mathematical law should not be confused with the question of physical proof. While it is true that the Newtonian equations are generally adequate in describing celestial motions with considerable accuracy, this in itself does not constitute a proof of physical attraction between bodies. The Newtonian equations which are now used in ordinary astronomy and in engineering would have the same mathematical validity regardless of the physical cause of motion. The tendency of bodies toward the earth would conform to these equations whether the

bodies were i) attracted by the earth, ii) endowed with an innate tendency toward an environment, or iii) moved by immaterial forces in space. In other words, as far as the equations are concerned, it makes no difference whether the bodies are mutually " pulled " or not. Therefore, the validity of the equations does not prove the physical cause of gravitation. The important point is that Newton himself did not prove the existence of gravitational attraction within masses; the very fact that Newton did not believe in such an explanation manifests this clearly. Furthermore, the validity of Newtonian equations does not imply the truth of such an explanation, for the equations would have the same validity regardless of the actual cause of gravity. Newton himself makes this evident when he says, " What I call attraction may be performed by impulse or by some other means unknown to me." [91]

Emmanuel Kant was fully aware of the fact that Newtonian attraction was not empirically demonstrated.[92] For him it was more important to justify what he considered to be a universal and necessary *laiv* of physics. This he did by reducing the law of Newtonian attraction to simple " relations of spherical surfaces of different radii." In other words, he reduced the law to spatial relationships between points of given mass. Therefore, for Kant the law is a universal and synthetic judgment because it is derived from the nature of space itself, an *a priori* condition of the mind.[93]

On the " certainty of the proof " of universal gravitation Newton says,

> As when a stone is projected obliquely, that is, any way but in the perpendicular direction, the continual deflection thereof towards the earth from the right line in which it was projected is a proof of its gravitation to the earth, no less certain than its direct descent when

[9*] Newton, *Optics,* Qu. 31, 3rd ed. (London, 1721), p. 351.
[82] Kant, *Prolegomena,* 38.
[83] *Ibid.*

suffered to fall freely from rest; so the deviation of bodies moving in free spaces from rectilinear paths, and continual deflection therefrom towards any place, is a sure indication of the existence of some force which from all quarters impels those bodies towards that place.[94]

A careful analysis of the argument shows that this is not so much a proof of universal gravitation as an assumption of universal gravitation. While the falling of a stone proves some kind of terrestrial gravitation, the " falling " of a planet toward the sun presupposes that the planet tends to move in a " straight line "—a proposition which cannot be proved logically or from the behavior of heavy bodies whirled in a sling. A certain universality may be assumed upon which to construct mathematical laws, but this is not to be confused with the actual proof of such a universality. In this sense Kant is more correct in reducing the law to the structure of mental space than are those who consider universal attraction to be an empirically proven fact.

The Newtonian law of gravitation is usually expressed this way: Every particle in the universe attracts every other particle with a force which is directly proportional to the product of the masses of the particles and inversely proportional to the square of the distance between them.[95] Thus if M and M' denote the masses of two particles and r their distance apart, the force (F) of attraction is equal to

$$G \times M \times M' \, r^2$$

where the constant multiplier G is the constant of gravitation and measures the attraction of two particles of unit mass at unit distance apart. Since the force is always proportional to the mass acted upon, and produces the same change of velocity whatever that mass may be, the change of velocity, or " pull,"

•* Newton, *System of the World,* n. 4, ed. Cajori, p. 552.

•'From A. Ramsey, *An Introduction to the Theory of Newtonian Attraction* (Cambridge, 1949), p. 20.

tells us nothing about the mass in which it takes place, but only about the mass which is " pulling." The accelerations due to different pulling bodies, as for instance that of the sun pulling the earth, with that of the earth pulling the moon, can be compared one against the other to determine the respective masses and accelerations. But as the mass of the earth is always taken as unity, its actual mass is not determined. Astronomical calculations deal only with the acceleration, the product of *G* times mass acting and not with the actual value of *G*.

To weigh the sun, the planets, or the earth, in pounds or kilogrammes, or to find *G,* we must descend from the heavenly bodies to earthy matter and either compare the pull of a weighable mass on some body with the pull of the earth on it, or else choose two weighable masses and find the pull between them.[96]

Over the past century and a half numerous attempts have been made to measure the gravitation pull between two known masses in an effort to determine the value of *G* and *M*. It is commonly thought that these efforts prove the existence of a universal gravitational pull.

Newton himself rejected the possibility of measuring any pull between terrestrial bodies, for the force would have to be incredibly small.

A sphere of one foot in diameter, and of a like nature to the earth, would attract a small body placed near its surface with a force 20,000,000 times less than the earth would do if placed near its surface; but so small a force could produce no sensible effect.[97]

However, many attempts have been made to measure such a force. Two types of experiments have been carried out.[93] The first type, such as the " mountain experiment " of Bouguer,

J. Poynting, *Collected Scientific Papers* (Cambridge, 1920), p. 360.

7 Newton, *System of the World,* n. 22, ed. Cajori, pp. 569-570.

Cf. Newman and Searle, *General Properties of Matter,* 4th ed. (London, 1950), pp. 54-62; see also Poynting, *op. cit.,* pp. 613-644, and his own efforts, *ibid.,* pp. 1-164.

Maskelyne, and others, as well as the " mine-method " of Airy and von Sterueck, tried to measure the horizontal pull exerted on a plumb-line by some determinable density of the earth. But these attempts to utilize large natural masses were of doubtful value due to the difficulty of calculating the quantities and to the impossibility of excluding extraneous influences. The second type of experiment, employed by Cavendish, Eotvos, Poynting, Heyl, and many others, tried to deal directly with the mutual pull between bodies of comparatively small size. In this case the supposed gravitational forces must be so small that refined methods of observation are needed, and all other forces affecting the body must be negligibly small, or accurately measured. One of the principal results of this type of experiment was the realization that a highly sensitive apparatus is needed to determine the " pull "—and therefore very susceptible to disturbing influences." However from a great number of experiments by different methods, due corrections being made, satisfactory values can be ascribed to *G* and *M*. Thus Poynting says,

> In the case of such a constant as that of gravitation, where the results have hardly as yet begun to close in on any definite value, and where, indeed, we are hardly assured of the constancy itself, it is important to have as many determinations as possible made by different methods and different instruments, until all the sources of discrepancy are traced and the results agree.[100]

One important observation, however, must be made about this attempt to measure the minute pull between two small masses. Supposing that the ideal experiment could be carried out, in which all disturbances could be eliminated (which is not the case at present) and a real " pull " detected, *this in itself would*

"* Cf. Poynting, *op. cit.,* pp. 632-3; 621-027; Newman and Searle, *op. cit.,* pp. 59-61.

[100] Poynting, *op. cit.,* pp. 43-44. It must be pointed out, however, that this was written by Poynting in his famous article of 1891, *On a Determination of the Mean Density of the Earth and the Gravitation Constant by Means of the Common Balance.*

not prove that bodies fall to the earth because of that force. There is no necessary connection, logical or philosophical, between a conceivably detectable " attraction " between bodies and gravity by which heavy bodies fall to the earth. The attraction may easily be caused by forces other than gravitation. The point is that the existence of some attractive force does not in itself prove that bodies fall to the earth because of that force; the identity of the two forces would have to be demonstrated. The tendency of mathematics is to unite as many phenomena as possible. This it can do because it *abstracts* from important differences which are found in reality. The mathematician's ideal is to describe all natural phenomena in a single equation; but this cannot be done without abstracting from differences which, to the natural philosopher, are extremely significant. The point is not to deny the validity of mathematical abstractions and universal unifications but to point out that they are abstractions.

From a philosophical point of view one of the principal defects of gravitational attraction—as a philosophical theory—is over-simplification. It assumes that bodies are themselves inert and that all motion must be conferred from without.[101] It considers characterless masses spatially distant from other masses, disregarding the intricate dependencies of every body upon the whole qualitative environment. Inert masses divested of qualities, spontaneity, and finality can certainly be conceived; in fact, such conceptions are very clear and distinct. But it is another matter altogether to make these abstractions the actual structure of reality. This is what Whitehead calls the " Fallacy of Misplaced Concreteness " in which abstractions are given real existence.[102] Whitehead insists that qualitative characteristics

[101] The distinction between inertial and accelerated motion is not relevant here, for inertial motion receives no explanation and accelerated motion is defined by the external force. Cf. " Natural and Compulsory Motion," THE NEW SCHOLASTICISM, XXVIII (1954).

[10g] Whitehead, *Science and the Modem World, ed. cit.,* pp. 64-70, 72 ff.

and intrinsic dependence upon the whole spatiotemporal reality is essentially relevant to every body actually existing. Bergson had previously objected to the " spatialization of time " in which the dynamic reality of temporal duration is turned into a series of static points. In other words, it is easy enough to conceive characterless masses, located in absolute space, isolated in time, and mutually attracting. But this is an over-simplification of the real state of nature as it is perceived in human experience. Relativity physics at least insists upon the essential dependence of every event upon the spatio-temporal environment.

A further philosophical difficulty is offered by the meaning of " gravitational force." Newton insisted very strongly that the force *(F)* operating between two bodies " is one single intermediate action, by which both approach nearer together "; the bodies " do not make two but one operation between two terms." [103] From a mathematical point of view this is precisely all that the quantity *F* signifies. But when the attractional theory is projected into a philosophical theory, the force of attraction must be considered as a physical reality; and the question arises, " What is it? " and " Where is it? " It is commonly thought that each particle has within itself a " force of attracting " other particles, so that there are as many " forces " as there are particles. But the important point to note is that the resident " force " has nothing to do with the body's own movement; it is posited to explain the movement of *another* body. Thus even though two bodies are said to attract mutually, the actual movement of any one body is explained by the pull of the *other*. Thus the whole function of the resident " force " is to account for the movement of other bodies. It has nothing to do with the body's own behavior. It is this aspect of attractional force which makes it so unintelligible. It is easier to see how an intrinsic force may account for the behavior of the body

[108] Newton, *System of the World,* n. 20, ed. Cajori, p. 569.

actually moving; and, indeed, it is logical to suppose that the performer in nature is itself accountable in some way for its own movements. The great variety of activity we see in the world, the intricate dependencies and variations, are intelligible only if we recognize the complex variety of things themselves— things which are not characterless masses but " events " vested with qualities and woven into the whole fabric of reality. An innate force which has no relevance to the body itself must be characterless and unintelligible, for it is empty and explains nothing. What is it? Leibniz was probably right when he called it " a senseless occult quality, which is so very occult that it can never be cleared up, even though a Spirit, not to say God Himself, were endeavoring to explain it." [104] An inexplicable force such as gravitational attraction may be useful in combating atheism,[105] but it does not contribute to a philosophy of nature. To replace the Aristotelian notion of "nature" by some force of gravitational " attraction " is not only to shift the problem, but to shift it to a position where it can never even be clarified.

In concluding this section we must emphasize again the vast difference between a mathematical science of nature and the philosophy of nature. A mathematical science necessarily abstracts from qualitative differences, causality, and even from the function of nature itself. Within this limited domain there is perfect justification and unlimited possibilities. The philosophy of nature is a distinct and vastly different science, the validity of which depends upon the whole of human experience concerning natural reality. It is only when a mathematical view is projected into a philosophy without recognizing its true foundations, that serious difficulties arise. These difficulties can be solved only by an analysis of meaning and a critical examina-

[105] Leibniz, *Philosophische Schriften,* ed. Gerhardt, III, 519.

[105] De Guevara y Basoazabal, *op. cit.,* pp. 156-7; also sermons of Richard Bentley, cf. Brewster, *Life of Sir Isaac Newton,* pp. 256-263.

tion of the historical and theoretical foundations of the divergent views of reality.

III. Einsteinian Relativity

A thorough examination of Einstein's theory of general relativity would bring out more clearly the point we are trying to defend. But a complete analysis of the modern view of gravitation requires much more than a few pages. However, without even initiating such an attempt, we must draw attention to a few features of the relativity theory of gravitation.

It has already been pointed out that the history of relativity arose because of certain doubts cast upon the fundamental concept employed in Newtonian physics.[106] Even as early as the middle of the last century questions were raised as to the meaning of " inertial motion," for inertial motion requires the existence of some absolute frame of reference according to which the motion of a body is uniform and directed in a straight line. C. Neumann, for example, presented certain paradoxes which follow from the Newtonian laws, but he thought that all difficulties could be removed by considering motion as absolute and determined in relation to a hypothetical body *alpha.*[10'1] Most physicists of the time were inclined to follow him or to postulate an absolute ether. Others, however, like Ernst Mach, preferred to maintain the relativity of all motion and to take issue with the law of inertia as expressed in Newtonian physics.[108] But no satisfactory theory of relativity was reached

[10]*Cf. also R. Dugas, *Histoire de la Mecanique* (Neuchatel, 1950), pp. 419-443.

[107] In our own day this opinion is followed by P. Hoenen, who identifies it with the absolute ether, cf. *Cosmologia,* 4th ed. (Rome, 1949), pp. 64-70, 493-497. " Ita ' corpus alpha,' quod a Neumann fingebatur, sese revelat ut ens reale: aetherem, quo ceterum iam indigemus, ut relationes locales corporum, inter quae sunt stellae fixae, oriri possint." *Ibid.,* p. 496.

[108] E. Mach, *The Science of Mechanics* (Chicago, 1907), pp. 222-238, 567- 573; *History and Root of the Principle of the Conservation of Energy* (Chicago, 1911), pp. 75-85.

until 1905 when Einstein successfully interpreted the Lorentz transformation and the Fitzgerald contraction on the basis of the constant velocity of light. In 1908 the famous mathematician Minkowski made a remarkable discovery concerning the Lorentz formulae. He showed that, although each observer has his own private space and private time, a public concept which is the same for all observers can be formed by combining space and time in a four-dimensional continuum.[109] But this combination of inertial systems, as we have already seen, introduces a " curvature " in the geometry employed. When Einstein extended his theory of relativity to include accelerated systems (general theory of relativity) a non-Euclidean geometry of the Biemannian type was used.[110] According to the general theory no preference is given to any particular observer in either inertial or accelerated motion; by using the " curvature " of Biemannian geometry any event may be described, which if true for one observer, will automatically be true for all. Since the special theory of relativity is considered to be a restricted case of the general theory, all events receive the same description and there is no distinction between inertial and gravitational motion.[111] From one point of view the general theory reduces all motion to gravitational, that is, accelerated motion; for this reason it is commonly called " Einstein's theory of gravitation." But from another point of view all gravitation is reduced to inertial systems; for this reason Sir Edmund Whittaker says, " What Einstein's theory really does is to abolish the old idea of gravitation altogether and to replace it by the idea of inertial frameworks." [112]

In this geometrical picture of the universe the central place

[10]" Cf. R. Dugas, *op. cit.,* pp. 468-473.

[110]H. Wevl, *Philosophy of Mathematics and Natural Science* (Princeton, 1949), pp. 67-110.

[111] See E. Freundlich, *The Foundations of Einstein's Theory of Gravitation* (London, 1924).

'-V1':" ' r >*m* *5tfsK<? *P'f'JiniftO'i.* £"f. *cit.,* p. 115.

is held by the " curvature " of space-time, which represents the actual path, or geodesic of the moving body. The degree of curvature depends upon the intensity of the gravitational field

2, which is specified by the values of $K^{\wedge}$ describing the distribution of motion and matter in that region. Therefore the Einsteinian law of gravitation, G>2 = K/12, expresses both the curvature of space-time and the amount of mass present, mass being measured by velocity. In other words relativity presents a purely geometrical picture of physical measurements.

Many popular works on relativity triumphantly speak of the abolition of Newtonian " forces " in their account of gravitation.[113] Gravitation is pictured as the result of the curvature of space-time, or the structure of the space-time continuum. That is to say, a heavy body falls to the ground because of the structure of the field; the field is so curved that the body must take that path. But a difficulty arises from the fact that the so-called curvature of space-time depends upon the presence and motion of the matter being considered. Dr. Whitrow refers to this ambiguity which constantly arises in explaining the theory of relativity.[114]

> The expressions for the energy and momentum of a given material system depend on certain numbers characterizing the structure of space-time, but these numbers in turn depend on the distribution of matter contemplated.[115]

This ambiguity inevitably arises when we try to think of Einstein's system as dealing with the philosophical structure of reality. The tendency is to project the system into a philosophical theory and to think of gravitation as a result of the spatio-

[113] For example, B. Russell, *The AHC of Relativity* (London, 1925); A. Eddington, *The Nature of the Physical World* (London, 1947) ; Einstein and L. Infeld, *The Evolution of Physics* (Cambridge, 1947), (actually written by Infeld).

[114] G. Whitrow, *The Structure of Universe* (London, n. d.), pp. 73-74.

[115] *Ibid.,* p. 74.

temporal structure of the universe. The imagination is tempted to form a mechanical view from the theory of relativity because this is a simple picture of phenomena. But such a view, supposedly based on relativity, is even less tenable than Newtonian attraction. To explain the movement of bodies as a result of the field or the " curvature " of space-time is to present a mechanical explanation without any real basis in relativity theory. In the first place, the so-called " curvature " is not a physical reality at all; it is strictly a geometrical curvature constructed from physical measurements. " It is not the space that is curved, but the geometry of the space." [118] There is no justification for giving that curvature physical existence and ior making it the cause of movement. In the second place, the curvature does not represent merely the field in which bodies move, as though field and mass were two distinct factors, but it represents field (energy) and mass as a single measurement. The basic tenet of relativity is the equivalence of mass and energy, $E = me^2$. In this equivalence there is no theoretical basis for distinguishing body and the surrounding field.[117] What actually results is a geometric continuity of various curvatures, representing a continuous " field " of various intensities. But here " field " is taken in a new sense—as seen through the eyes of geometry. Many popularizers of relativity are perplexed by these difficulties. Bodies and the surrounding environment are obviously distinct realities, yet in relativity theory they are one. There are obviously distinct realities in the universe, yet relativity considers all as a single continuum. There must be some cause of movement, but relativity can offer no cause. The solution of these difficulties lies in the fact that the theory of relativity is not a philosophical theory, but a *mathematical* theory of nature.

[116] E. Whittaker, *From Euclid to Eddington, ed. cit.,* p. 40.

[117] H. Weyl, *Philosophy of Mathematics and Natural Science* (Princeton, 1949), p. 171; cf. also Einstein and Infeld, *Evolution of Physics, ed. cit.,* pp. 255-258.

The important point here is that a mathematical theory and a philosophical theory of nature are *two specifically distinct sciences,* each of which has a determined and limited role in human knowledge. The great value of Einstein's revolution is that it brings out more clearly than ever the determined character of a mathematical theory of nature. The scholastics had always maintained a distinction between natural philosophy and the mathematical sciences of nature, the *scientiae mediae.*[11]* But the sudden development of these sciences in the seventeenth century dislodged natural philosophy and the mathematical theory became the accepted philosophy. That is to say, the valid *mathematical* view was projected into a philosophy by a method of simple transference; abstractions became realities. Qualities, which are necessarily relinquished in mathematical abstraction, were denied also in nature. Functional dependencies in mathematics became mechanical causes in nature; and true causality, which is inconceivable in mathematics, became inconceivable in reality. Some philosophical view of nature has always been necessary for man; and it is obvious that human experience has something to say about its formation. The question is, how much can mathematics *dictate* about such a philosophy? From the seventeenth century to our own day it has been thought that a complete dictatorship exists; that a one to one relationship obtained between mathematics and philosophy. But with the theory of relativity such a one to one relationship is impossible, for if it is carried out, the greatest certainties of experience are rendered nonsensical. The mathematical theory cannot be *simply* transferred to the world of human experience, which is the world of philosophy. Such a simple transference is the " Fallacy of Misplaced Concreteness," to use Whitehead's ac- acurate expression. Therefore, the theory of relativity itself

[11S] St. Thomas, *In Boeth. de Trin.,* V, 3, ad 5, 6, 7; *In II Phys.,* 3, nn. 8-9; Averroes, *In II Phys.,* comm. 18 (Venice, 1574), VI, fol, 55r, etc.

demands a new philosophy, which is not a mere projection of mathematical abstractions but a philosophy which corroborates and justifies the mathematical theory. The relationship between mathematical theory and a true philosophy of nature is not one of identity or simple projection; nor is it one of amicable isolation. Mathematical theory and the philosophy of nature are truly distinct sciences; they differ in foundation, method, knowledges alue, and logical significance. But both constitute valid knowledge of the world we live in.

The fundamental difference between the two types of knowledge may be expressed briefly. The scope of natural philosophy is the world of human experience regarding nature. Whatever is given in human experience must be accepted; and this includes the nature of man himself. The character of mathematical science lies in the nature of mathematical abstraction. A mathematical theory of nature is based on measurements and measurements alone. Whatever cannot be measured is of no use in mathematical theory. But to the natural philosopher even the non-measurable data of experience are important. Since, therefore, mathematics leaves out of consideration the non- measurable data of experience, it is clearly quite distinct from philosophy, which considers the whole of that experience.

From our study of gravitation it is clear that the theory of relativity is incompatible with the philosophical theory of mechanical attraction. Indeed it is incompatible with the whole outlook of all the mechanical philosophies proposed throughout the centuries. For reasons strictly within the domain of mathematical abstraction the theory of relativity forces us to reject the " simple location " of isolated bodies, as Whitehead has pointed out so clearly.[119] It forces us to recognize the reality of temporal emergence, a reality which Bergson fought so hard to defend. Furthermore the theory of relativity forces us to admit

[110] Whitehead, *Science and the Modem World, ed. cit.*

a spontaneity which is *given* and essentially dependent upon the environment. The spontaneity of nature as an active principle, the intricate dependencies of bodies mutually and upon time as well as upon environment, and the internal striving for some end, are all essential to the Aristotelian philosophy of nature. Thus the Aristotelian theory of nature and gravitation finds a satisfactory complement in Einsteinian relativity.

Conclusion

The problem of gravitation is extremely difficult. Why does a body fall to the ground? The mind would like to give a simple reply, but a simple reply is often an over-simplification of a very complex reality. Furthermore, the views which have been given in explaining gravitation involve a particular outlook upon the whole of physical reality; and many of those outlooks have been formed by unjustifiable assumptions, uncritical acceptance of " proof," or even by personal prejudice. Concerning the problem of gravitation, as in other problems, what is needed ia a careful analysis of the meaning implied in various views and a critical examination of their historical and theoretical foundations.

In examining the Aristotelian view of gravitation we have seen that there are two essential factors: an intrinsic principle of spontaneous movement, called " nature," and a suitable environment, or place, which is intended by the body seeking its own fulfillment. Nature must be understood as a principle of behavior actually given in experience. That is to say, " nature " is strictly a relative concept, the content of which is merely that which is actually experienced. " Nature " must not be conceived as an absolute entity lodged in bodies or as an " efficient mover," for such a notion, besides being contrary to the actual teaching of Aristotle and St. Thomas, merely shifts the explanation to an entity which can never be known. As a relative term, " nature " merely signifies the behavior that is actually known and the fact that it is spontaneously given; it is not an entity postulated behind known behavior to which an explanation can be shifted. In other words, the concept of nature involves the acceptance of observed characteristics as necessarily given. With

regard to the environment which is sought in natural motion we have seen that it is primarily a qualitative reality which a particular nature needs in order to achieve fulfillment of being. Secondarily, this place must have a certain immobility in order to account for the relational character of movement; but it is only a relative immobility which is justified in our conception of " place." That is to say, spatialization of place fails to account for the actual movement toward one place rather than toward another; and attributing absolute immobility to " place " is without real meaning. Therefore, we must conclude that the natural place of terrestrial bodies is essentially a qualitative environment which has relative immobility, at least as far as our knowledge is concerned.

An examination of the Newtonian view of gravitational attraction shows that Newton himself did not maintain the view promulgated under this name. In his personal view he attributed the cause of gravitation to God Who operated through absolute space, His extension and His " sensorium." But the mechanical laws according to which such gravitation took place were conceived by his followers as representing a mutual attraction of all particles throughout space, so that bodies fall to the ground because of the gravitational pull of the earth. Such a gravitational pull, however, has never been demonstrated by either Newton or his successors. Even the success of the mathematical laws does not prove physical attraction because of the character of mathematical abstraction. With regard to planetary movers we have seen that the law of inertia has not abolished the need of spiritual movers, but rather it has abolished the question of movers. With regard to terrestrial motion we have seen that the validity of the mathematical equations has nothing to do with the actual cause of gravitation, for those laws would have the same validity whether the cause were gravitational " pull," natural tendency, or spiritual forces. Therefore, gravitational attraction is not a physically proved explanation of gravitation.

Furthermore, the whole Newtonian picture of gravitation involves unwarranted assumptions about absolute space, time, and inertial motion, which amount to an oversimplification of a mathematical as well as of a philosophical theory of gravitation. If the whole of human experience is to be taken as a criterion, the philosophical theory of gravitation based upon mathematical theory is untenable for it involves assumptions which conflict with actual experience; and it renders a rational explanation of movement forever impossible by reducing it to an inexplicable force called attraction. The ambiguities of Newton's mathematical theory, moreover, led physicists to reject the Newtonian view of the universe and to replace it with the theory of relativity.

We have pointed out that the theory of relativity is essentially a mathematical theory, describing the measurable state of the universe in terms of non-Euclidean geometry. Although the tendency is to project this theory into a philosophical theory, every attempt to do so distorts the imagination or conflicts with the fundamental tenets of relativity t[1] eory. This apparent irreconcilability brings out most clearly the real difference between a mathematical and a philosophical theory of nature, which rests in the fact that mathematics abstracts from certain values of human experience and constructs its geometry to conform to physical measurements. Therefore, a simple transference of mathematical values into a philosophical theory is impossible; and an equivalent or congruent theory of gravitation is needed to supply the philosophical basis. Provided the distinction of the two sciences, mathematical theory and natural philosophy, be clearly kept in mind, it can be said that the Aristotelian theory of nature and gravitation offers a realistic basis and justification for the theory of relativity in its essential content.

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