things." (Fn.2) On the other hand, exclusive preoccupation with
natural substances or with material causes leads to a neglect of
final causes which would be justified only if there were no
separated substances, for "if there is no substance other than
those which are formed by nature, natural science will be the
first science; but if there is an immovable substance, the science
of this must be prior and must be first philosophy, and universal
in this way because it is first." (Fn.3)

The internal organization of the physical sciences, that is,
the differentiation of problems and of branches of physical
inquiry devoted to consideration of them, depends in the Aristote-
lian philosophy on the choice of method, and the method in turn
is determined in part by the complex variety of things discernible
in the world and in need of classification, in part by the princi-
pies and causes which are known after experience of things, which
are assumed as basic in physics, and which are themselves exa-
mined in general in metaphysics. If the problems of physics are
approached by way of method, then, since kinds of proof are dis-
tinguished by differences in principles, the internal organization
of the physical sciences can be sketched by indicating the proper
principles of those sciences; the characteristics of the principles
which are peculiar to physics, in turn, can be apprehended in
opposition and contrast to the principles of mathematics, for
such differentiation of the two sciences is a favorite device in
the method by which Aristotle treats are of the basic problems of
metaphysics. The methods of mathematics and physics are con-
trary both in respect of the manner in which their essential
definitions and principles are established and in respect of the
manner in which their demonstrations follow necessarily from
their proper principles; yet those two sciences treat essence
and seek necessary inferences in fashions which share, in respect
of both, a common contrariety to the method of metaphysics. The
definitions of physics are contrasted to those of mathematics in
that they must take into account matter as well as form, while
the definitions of mathematics involve only the continuum, which
is an "intelligible matter," and therefore they require no refer-
ence to existent things or to the sensible matter of such things.
(Fn.4) The definitions of physics are set up by induction which
takes account of matter and motion, while the definitions of
mathematics are set up by an abstraction from matter and motion.
The demonstrations of physics and mathematics respectively take
their distinctive characters from the definitions of each science,
and therefore the "necessity" of the demonstrations is in both
cases hypothetical, that is, dependent on the assumptions that
have been made, and is, as a consequence of the differences in
definitions, hypothetical in opposed manners. In mathematics,
if one assumes the premisses, the conclusion follows; but it is
impossible to reason back from the conclusion to a unique set of
premisses. If a straight line is defined in a given manner (to
use Aristotle's example), certain conclusions follow concerning
the angles formed by straight lines; but it would be impossible
to infer from those conclusions to only that definition of a
straight line. Conversely in physics, if a given consequence
has been observed in the processes of change, one may reason back
to its necessary antecedents; but it would be invalid to reason
from the existence of the conditions that the event must inevita-
bly follow. If a house exists, one knows that certain antecedent
processes must have been completed; but observation of any of the earlier processes of assembling materials or of building foundations or walls would not justify the inference that the house will necessarily be built. This differentiation of physics from mathematics permits Aristotle further to make clear the place of the practical sciences and the arts in relation to physics, for they too make use of the sequence of antecedents and consequences; but whereas the physicist reasons back from the consequences to necessary or probable antecedents, the artist begins with antecedents to work for the accomplishment of consequences; and whereas artist and mathematician operate in the same direction, the artist from his materials and the mathematician from his hypotheses, the former works toward his principle, which is the final cause, while the mathematician reasons from his principles. The functions, though distinct, sometimes meet in a single person, as when the physician as "scientist" considers the conditions of health and the antecedents which precede it, while as "artist" he takes advantage of one such condition in his patient to make use of it in effecting a cure. (Fn.5) The distinction between physics and mathematics moreover makes clear the function of metaphysics in the scheme of a philosopher who refused to identify the problems of being with the problems of quantity and change. There is no demonstration of essence or substance, for the particular sciences start from the essence of the things of which they treat (either exhibiting it to the senses or assuming it as a hypothesis), and they do not raise even the question whether the genus with which they deal exists or not. (Fn.6) Such assumptions are possible in the particular sciences because being and the conditions of being have been examined as such, apart from questions of differentiation into the kinds of being, and the specification of the kinds of substances has been made. The necessity which binds together two aspects of being or two properties associated in the definition of a thing is absolute, not hypothetical, for it follows from the essence of a thing rather than from the determination of its existence, and the demonstrations of mathematics and physics, being inferences from assumed essences, derive their hypothetical necessity from the necessity which is absolute in their principles and definitions. Thus, considerations of the relation of being and unity, which lead to the metaphysical doctrine that everything which is in some sense one, would justify the attribution of unity— as consideration of the nature of a thing, which is stated in its definition, would justify the attribution of any property implicated in the definition—to the thing with absolute necessity; the hypothetical necessity of the demonstrations of mathematics and physics are inferences from a substance or definition.

Although Aristotle is reputed to have written on mathematics, optics, astronomy, and music (which were included by the Greeks under mathematical subjects), none of his writings on mathematics has survived. Aristotle's conception of that one of the theoretical sciences can therefore be gathered only by inference from his statements concerning mathematics in works on other subjects, particularly from his writings on metaphysics and physics. We have, on the other hand, abundant evidence not only of his conception of physics but of the detailed manner in which he worked it out, for a great part of his extant works falls under that classification, and the physical writings of Aristotle afford the best examples.
of his scientific method, of his effort to unite metaphysical inquiry into principles with empirical investigation of specific instances, and in general of the operation of his multiple classifications. The character and sequence of problems treated in the physical works, no less than the reasons for the diversification of his method, can be seen best in the interplay of three classifications: (a) the kinds of substances or natures, in which contribution of metaphysics to physics is immediately apparent, (b) the kinds of causes, by which the principles of the various branches of physical inquiry are differentiated, and (c) the kinds of motion, by which phenomena are classified and brought under the principles of the appropriate sciences.

The classification of natures in Physics is precisely the same as the classification of substances in the Metaphysics, that is, it is a division into elemental bodies and their compounds, plants and their parts, and animals and their parts. What distinguishes the physical treatment of natures from the metaphysical treatment of substances, however, is that natures are considered in terms of an internal principle of motion and rest which they possess, whereas, substances are examined in terms of the conditions of their existence. (Fn. 7) Moreover, whereas the investigation of these things enumerated as natures and substances, all of which are destructible, led in the Metaphysics to an investigation of indestructible substances, both those which are unmoved and those in motion; the investigation of physics, reversing that order, begins with the influence of indestructible things on motion and with the motions of such indestructible things as move, preliminary to the investigation of the motions of the destructible things which constitutes the large bulk of physical inquiry. Moreover, as in metaphysics the treatment of being and the classification of kinds of beings were made possible by means of the four causes, particularly two of them, form and matter, in the case of destructible substances, so too the classification of the four causes plays across the classification of natures in the treatment of natural motions, with particular emphasis on two of the four.

Now, the causes being four, it is the business of the physicist to know about them all, and if he refers his problems back to all of them, he will assign the 'why' in the way proper to his science — the matter, the form, the mover, 'that for the sake of which.' The last three often coincide; for the 'what' and 'that for the sake of which' are one, while the primary cause of motion is the same in species as these (for man generates man) and so, too, in general, are all things which cause movement by being themselves moved; and such as are not of this kind are no longer inside the province of physics, for they cause motion not by possessing motion or a source of motion in themselves, but by being themselves incapable of motion. Hence there are three branches of study, one of things which are incapable of motion, the second of things in motion, but indestructible, the third of destructible things. (Fn. 8)

Finally this double classification, of natures and of causes, if brought into relation with the classification of motions into three kinds, since motion is relevant to only three categories, (a) alteration or change of quality, (b) increase and diminution or change in size or quantity, and (c) locomotion or change of place; but motions fall in the class of changes, and among the
kinds of change, in addition to the three kinds of motion, there is change properly so called, in the category of substance, that is, generation and destruction; and the problems of motion, though not themselves in the category of substance, must ultimately be related to problems of generation and destruction.

The chief characteristics of the study of motion are investigated and stated in the work which we still call the Physics, and which Aristotle sometimes refers to by some form of that title, and sometimes refers to in parts, to the first four books usually as On nature, and to combinations of the later books as On motion. It treats, however, not only of the physical sciences as such, of the principles of motion in general and the causes and conditions of motion, and of related general considerations such as the characteristics of the mover and the moved, the infinite, place, time, and the void, but proceeds in the second half of the work to the classification and differentiation of the kinds of motion in terms which recall the first of the three kinds of physical problems suggested by the treatment of natures and causes, i.e. the treatment of things which are incapable of motion. A nature is a cause of motion, and since natures are composite of form and matter, the causes of natural phenomena may be found in purposes or in antecedent conditions, for the end is the form in nature and necessity is the matter. (Fn.9) A physical process may be explained either in terms of the material conditions which preceded it, or in terms of the end toward which it tends, the latter explanation being in one sense the more fundamental, and yet in another sense exceeding the limits of considerations proper to physics. It is the cause of motion in this sense that is treated in the last half of the Physics, and the explanation of natures culminates in Book vii of that work—much as the explanation of substance culminated in Book xii of the Metaphysics—in an unmoved mover which provides for the motion of eternal things and, indirectly, for the combinations of form and matter in contingent things. It treats therefore (to consider the subject matter of that portion of the Physics in terms of natures) of eternal unmoved things; an unmoved mover moves (to consider the subject in terms of causes) by attraction or as a final cause; and the motion it induces, since it is continuous, infinite, and eternal, is (to make use of the classification of motions) local motion.

The same classifications determine the sequence and manner in which the remaining subjects of physical inquiry are treated. On the heavens takes up, in two books each, indestructible and destructible things which are in motion, and the inquiry is turned to those two classes of things by shifting the consideration from final to material causes. The treatise seeks, not the originating causes of motion, but the character of the "wholes" in motion. Aristotle argues that a "while" is so designated not in respect of any form, but in respect of the matter involved, and the treatment of the "universe" is therefore a treatment of three-dimensional magnitudes (which alone among magnitudes are complete) of bodies. The first two books are devoted to examining the nature and movement of heavenly bodies; the second two books to examining the nature and movement of terrestrial bodies. The motions of both are local motions, but since the motions of heavenly bodies are circular and eternal, Aristotle argues that the bodies are composed of a "fifth body" or element, distinct from the
terrestrial elements, ungenerated, indestructible, and subject to
to no motion except eternal circular motion. On the other hand, the
natural motions of terrestrial bodies are finite and in straight
lines, upward and downward, and the elements of which these
bodies are composed are the customary four, earth, water, air,
and fire, which are subject to all the kinds of change and motion,
generation and corruption, alteration, increase and diminution, as
well as to local motion. Although the second half of On the heavens
deals with destructible things in motion by considering their
material causes, yet since only local motion can be determined by
the relation of parts and wholes, the elements are considered only
in terms of those of their characteristics which are relevant to
local motion — their lightness and heaviness (which are related
as form and matter) — two of the four elements being classified as
heavy, and two as light. Destructible things, which are treated in
terms of their elements in the second part of On the heavens, are,
however, subject to other motions besides local motion, and the
treatise On generation and corruption proceeds to a fuller inquiry
into changes of substance, quality, and quantity. These changes
require the analysis of the four elements into a common matter and
into two pairs of contrary qualities assembled in the four possible
combinations of hot and cold with wet and dry, (Fn.10) and since
the causes thus far considered, the final and material causes,
are insufficient to account for such combinations or for such
changes, the inquiry proceeds by use of the efficient cause which
is proper to generation and corruption. (Fn.11)

The whole range of phenomena on the sublunary side of the
moving stars requires other explanations than the statement of the
ultimate end of all things, or of the ultimate constituent elements
of all things, or even of the conditions that bring particular kinds
of things into existence. The elements themselves do not have
characteristics which are absolute and fixed, but they are influ-
enced by the traits of elements and compounds contiguous to them,
and, conversely, purposes and final causes can seldom be discerned
except in the case of the more highly organizes bodies. There is
an extensive and important class of phenomena which can be
treated only in terms of the proportion or mixture of the influences
exercised in their occurrence or in the ratio of elements which
enter into combination (not mere aggregation, as Democritus thought)
in their composition. These phenomena are treated in the Meteorology
and include not only those interactions of the elements and their
qualities which result in comets, rains, snows, earthquakes,
lightning, and like occurrences, but also the combination of the
elements into chemical compounds and organic structures, in which
the numerous properties and functions which are discerned by the
senses in perceptible substances first come into existence. In all
such phenomena and in all such bodies, the elements are the
material causes, and the influence of the heavenly bodies con-
tributes to the forms they assume (for man is begotten by man and by
the sun as well), but the discernible forms vary in distinctness
with the proximity of the phenomena to the motion of the stars and
with the perfection of the organic structure of bodies. Since in
many instances a ratio or logos is the sole manifestation of the
form, the formal cause emerges to a new importance in the treatment
of the problems involved in such occurrences and compositions.
The influence of the eternally moving heavenly bodies is most obvious in the region nearest to the motion of the stars (in such phenomena as the Milky Way, the comets, and the motions of meteors); the intermediate region, which is next in order to the first and which immediately surrounds the earth, is common to air and water (in which region occur such phenomena as rain, clouds, mist, dew, snow); (Fn.12) and finally in the region of the earth the influence of the stars is too general to supply specific causes, and causes are sought therefore, formal as well as material, in the actions and combinations of the elements. The elements, by virtue of their qualities, are themselves both material and efficient causes, for the wet and the dry (or air and earth which are equated with them) are passive, and the hot and the cold (or fire and water) are active, and of the latter two qualities, cold is matter or passive, and heat active. (Fn.13) There are three stages in the constitution of things by composition. First the simple bodies or elements may be considered in terms of their qualities; second the elements are compounded in "homogeneous bodies" (like the metals among inanimate things, or the wood and bark of plants, or the tissue and bones of animals) in which new simple qualities are discerned by perception; these in turn are organized into "heterogeneous bodies" (like organs and parts, hands and faces) in which functions and purposes are for the first time manifestly clear.

The examination of causes therefore runs a continuous course from the elements to the heterogeneous bodies, depending first on material causes as their primary mode of explanation until formal causes are eventually discerned most clearly in the ends and final causes of organs and instruments of action.

The homogeneous bodies are made up of the elements, and all the works of nature in turn of the homogeneous bodies as matter. All the homogeneous bodies consist of the elements described (sc. earth and water), as matter, but their essential nature is determined by their definition. This fact is always clearer in the case of the later products, of those, in fact, that are instruments, as it were, and have an end; it is clearer, for instance, that a dead man is a man only in name. And so the hand of a dead man, too, will in the same way be a hand in name only, just as stone flutes might still be called flutes; for these members, too, are instruments of a kind. But in the case of flesh and bone the fact is not so clear to see, and in that of fire and water even less. For the end is least obvious there where matter predominates most. If you take the extremes, matter is pure matter and the essence pure definition; but the bodies intermediate between the two are matter or definition in proportion as they are near to either. For each of those elements has an end and is not water or fire in any and every condition of itself, just as flesh is not flesh nor viscera viscera, and the same is true in a higher degree with face and hand. What a thing is is always determined by its function: a thing really is itself, when it can not do so it is that thing only in name, like a dead eye or one made of stone, just as wooden saw is no more a saw than one in a picture. The same, then, is true of flesh, except that its function is less clear than that of the tongue. (Fn.14)

On the level of the elements, then, the formal cause is sought in the active qualities of the elements; on the level of homogeneous
bodies in the ratio or definition of their composition; and on the
level of heterogeneous bodies, for the most part, purpose and func-
tion emerge for the first time in a sufficiently clear form to be
of service in scientific explanation.

The importance of the multiple classifications which determine
Aristotle's treatment of physical problems may be seen in both
the method and the order of his explanations. With respect to the
first, it is important to observe that no uniform explanation is
used, but the method is suited to the problems which are under
consideration. Although the principles are the common principles
and causes examined in the Metaphysics, they enter into each of the
sciences in particular guises. With respect to the second, the
sequence of explanation does not follow a single order supposed
to exist in the nature of things but is determined quite as much
by considerations, on the one hand, of available techniques for
examining specific problems and, on the other, of ascertained or
ascertainable knowledge about them. Specifically, the commentators
on Aristotle have frequently treated the universe which is inves-
tigated in his scientific writings as an ordered series of hierarchies
and functions. Although such description is accurate of the universe
as Aristotle envisages it, it does not determine the case of the
scientific knowledge we possess of the universe or the manner appro-
priate to investigation, for the inquiries of science proceed, not
but running up hierarchies from the elements or by running down
hierarchies from God, but by reordering the innumerable kinds
and aspects of things by means of such instruments as are at the
disposition of man and adequate to the nature of phenomena. The
investigation of the phenomena involved in changes perceived by
our senses in composite bodies is thus inserted between the
extremes of a theory of their constituent elements and a theory of
the universe as a whole, and notwithstanding the continuity of the
scale of being, the principles of explanation for the middle region
are different from the principles which govern the explanation of
either extreme. This encircling scheme of physical explanation is,
moreover, important to the understanding of Aristotle's treatment
of biological phenomena, for they too are inserted into the
middle region of that scheme of being. Biological processes at
one extreme approximate to and are explained by the elements,
the homogeneous and the heterogeneous bodies which enter into the
physical constitution of animals. At the other extreme they
serve purposes and exercise functions which become more explicit
and deliberate as the organism becomes more complex and as the
animal approaches awareness of his own ends and of the nature of
things.

Biological problems form one portion of physical inquiry, but
they introduce a new complexity of function in the subjects studied
and so open the possibility of greater specificity in the discrimina-
tion of causes. Therefore a new formulation of the use of form and
matter and of the manner of inquiry into ends and necessity may
be introduced in treating the phenomena of life, without departing
from the fundamental principles of physical science. The form
which determines the phenomena of life may be examined specifically
without relying, at the one extreme, on a mere statement of the
bodily constituents discoverable in the animal, or at the other
extreme, on a mere statement of the existence of a final cause of
all motion. The treatise On the soul is devoted to inquiry into
the cause and principle of the living body in the sense not only of formal cause, but as efficient and final cause of living as well. ( Fn,15) Aristotle is careful to point out that the definition of the soul is physical in that it requires specification of the organic body as matter, but he also points out among the peculiarities of this definition that it is, in its final form, comparable to a "functional" definition in mathematics; that is, it is related to the kinds of souls and to the powers of any soul, not as a physical definition of a species is related to the individual members of that species, but as the definition of mathematical "figure" is related to the kinds of figures.

The problems envisaged in the treatment of the soul and the problems and functions to which its definition must apply include those of generation, nutrition, and growth (which animals share with plants), sensation and locomotion (which man shares with other animals), and thought (which is peculiar to man among animals). Of these functions, generation and locomotion are barely touched on in the treatise On the soul; nutrition and growth are treated briefly; while the various processes involved in sensation and thought are elaborated at length. The reason for this may be stated in terms of questions of method: the definition of the soul was sought as a principle from which to demonstrate the properties and functions of the soul, but the investigation which would lead to such a definition must reverse, as does the normal procedure in all investigation, the order of demonstration (since we begin in investigation with what is most obvious to us in experience to work back to definitions and principles of demonstration) and the final stage of the investigation is the first stage of the demonstration. Functions and processes of living things, however, are not in all cases immediately perceptible to the senses as are the properties and processes with which we begin in the investigation of inanimate objects, and they cannot therefore be used as an initial step in establishing the definition of the soul of which they are functions and processes. But some of them, particularly those investigated in On the soul are determined, not merely by the animal of which they are functions, but by the objects on which they are exercised. Inquiry into the phenomena of life is therefore frequently begun with the objects on which the functions studied are exercised (such as food or the objects of sense), and the operations of the soul are explained in terms of the object, the powers in terms of the operations, and the soul itself in terms of its powers or parts. The definition of the soul, finally, is the principle of the demonstration of such processes, and it must be such as to account, in some animals, for the possession of all of the functions enumerated, in others, for the possession of some few; as a consequence, definitions and demonstrations in the biological sciences may be said with respect to this functional character to resemble those of mathematics. (Fn.15)

The formal consideration of the functions of life in terms of the definition of the soul, which is adapted to any and all such functions, requires supplementation by what might be considered the material treatment of some of those functions, that is, the inquiry into which of them is common to many animals, and which is peculiar to some. The Short natural treatises supplement On the soul in just this fashion by inquiring into the senses and sensibles, memory and reminiscence, length and brevity of life, youth and
old age, life and death, respiration, for these inquiries have a
generality, comparable to and yet the converse of those pursued in
On the soul based on the characteristics of bodies, on analogous
organs, or similar objects. (Fn.17)

The four biological treatises emphasize the functions which
are treated in least detail in the On the soul: processes of
generation, locomotion, growth, and nutrition. Moreover, they
make use of the principles established in both the physical treatises
proper and in On the soul, the former for material principles (since
the bodies of animals are composed of elements combined into homo-
genous and heterogeneous bodies), the latter for formal principles
(since the final cause is more clearly discernible in man than
in other animals). (Fn.18) Finally, the continuous scale which
begins with the sequence of elements and runs through the compo-
sition of elements into homogeneous bodies, to the organization of
such bodies into heterogeneous organic bodies, is extended upward
through the kinds of animate beings. Once more, however, as in
physics proper, neither the order of investigation nor the reverse
order of demonstration in the biological sciences reproduces in
sequence the order of the substances in nature. Indeed the very
continuity of the series in some cases resists classification by the
genera and species of science.

Nature proceeds little by little from things lifeless to
animal life in such a way that it is impossible to determine the
exact line of demarcation, nor on which side thereof an inter-
mediate form should lie. Thus, next after lifeless things in
the upward scale comes the plant, and of plants one will differ
from another as to its amount of apparent vitality; and, in a
word, the whole genus of plants, whilst it is devoid of life
as compared with an animal, is endowed with life as compared
with other corporeal entities. Indeed, as we have just remarked,
there is observed in plants a continuous scale of ascent towards
the animal. So, in the sea, there are certain objects concerning
which one would be at a loss to determine whether they be animal
or vegetable. (Fn.19)

By means of the causes this closeknit continuity is examined and
reduced to the multiple classifications of science, in which parts of
the hierarchy of beings are pieced together at those particular
points where observations have been more nearly complete or more
fortunate. As a result, the four biological treatises break up
the subject matter of animate motions in a fashion broadly compara-
able to the distribution of the problems of motions in bodies
as treated in the four physical treatises.

The investigation of biological problems, then, is introduced
into the middle region between inquiry into the properties of heter-
genous bodies (that is, it involves a degree of greater complexity
than the investigation of the composition of organic and inorganic
compounds) and inquiry into the sensitive and rational processes
of man (which approach close to the activities of God). Once
again, the method tends throughout the four stages of the inquiry
to a middle course of explanation: where Democritus might investi-
gate the functions of animals in terms of the material constituents
of their bodies, or the Platonists might confine their study to
the proportions exhibited in the composition of souls and bodies,
Aristotle pursues "physical investigation" into matter and form,
and he analogizes the functions of animals, not to the motions of
atoms nor to the motions of the stars, but to the parts and powers of man.

The multiple basis for the classification of biological phenomena is set forth in the monumental History of animals. This treatise is a vast collection of data, most of it the extraordinarily precise statement of Aristotle's personal observations, some of it restate-ment of the reports of travelers, accompanied often by the expression of reservations concerning the credibility of the information, some of it tales of such incredible marvels as to tempt scholars to question the authenticity of the passage or the scientific acumen of Aristotle. The treatise serves a function in Aristotle's biological investigations comparable to the function in the investigation of social phenomena of the collection of political constitutions which he made preliminary to formulating his political theories, or the collection of "arts of rhetoric" which probably guided him in considering the problems of persuasion. Like those collections (so far as we know them) and like the better-known and less ambitious assemblages of data in the physical treatises which have already been examined, it is not a mere factual aggregation of data nor an attempt to relate animals in a single schematism of inter-related species. The highly integrated formal scheme in which its information is presented depends on the interplay of two basic sets of classification which are related to each other as form and matter; the first a multitudinous set of classifications of animals on a great variety of bases (which is set forth in the first six chapters of the first book of the History of animals) and the second an equally numerous set of classifications of the parts of animals on similarly diversified bases (which is set forth in the last eleven chapters of that book).

The data are arranged therefore as comparisons and contrasts of many animals examined successively on many points, and the hierarchies of nature are, as a consequence, reduced to three grades of likeness, (1) those of members of species to each other (since the differences of individuals are not perpetuated by nature), (2) those within "greatest genera" between species whose bodily parts differ only in degree, that is, in number, size, softness, hardness, smoothness, roughness, and (3) analogies between the greatest genera, as of arm, foreleg, wing, and fin, or of bone and fish-spine, or of feathers and scales. No attempt is made to reduce the data to a rigidly hierarchized master classification, and there are, moreover, numerous isolated species which fall under no "greatest genus." Whereas the functions of animals were treated in terms of the common characteristics inferred from their common objects in On the soul, animals are classified in the History of animals according to the peculiarities of their exercise of functions, and it is because of this emphasis on differences in common functions (rather than on identities to be found in operations on common objects) that precisely the functions which were treated briefly in the former treatise become the center of classification, generation and locomotion being particularly prominent, and the peculiarities of diet and the effects of the need for food on the habits and survival of animals being likewise developed at length.

(Fn.20)

The formulation of the general method of the biological sciences to which the first book of On the parts of animals is devoted is an adaptation to the problems of biology of the use of the causes previously developed in the physical treatises. As is in general
the case in physical investigation, a double explanation is sought: first, the reason or definition which is based whenever possible on the end, and second, the necessity according to which antecedents are traced back from observed consequents. The final cause is the first cause and constitutes the nature of the animal. Once more the older physicists are criticized because they neglected one of the causes and tried to explain things by matter alone; the whole animal and its parts and functions must be considered.

It is plain, then, that the teaching of the old physiologists is inadequate, and that the true method is to state what the definitive characters are that distinguish the animal as a whole; to explain what it is both in substance and in form, and to deal after the same fashion with its several organs; in fact, to proceed in exactly the same way as we should do, were we giving a complete description of a couch. (Fn.13)

The explanation of animals and their parts is based on the distinction of the three degrees of composition which is repeated and adapted in considerable detail from the Meteorology: the physical substances (hot and cold, dry and wet), the homogeneous parts or tissues, and the heterogeneous parts or organs. On the basis of those distinctions in their matter, the organs themselves are treated in terms of their functions and purposes, or, to state the order of inquiry in Aristotle's terms, the material causes are treated first, then the final causes or forms. (Fn.22) The treatise On the walk of animals takes up problems of local motion in much the same fashion that the motions of the elements were considered in the On the heavens by treating of bodies and dimensions, and so constructs a kind of animate mechanics of limbs according to their numbers and kinds of their joints. The treatise On the generation of animals, finally, starts with a recapitulation of the four causes, in which it is pointed out that three of the four causes have been treated adequately in their application to animals and that the consideration of one, the efficient cause, remains, and this cause, in the biological as in the strictly physical realm, is proper to generation and corruption. The application of the conception of causes to the problems involved in the generation of animals is one of the great achievements of Aristotle's biological inquiries, for it is the ground of his brilliant criticism of the earlier Hippocratic theory of pangenesis, while the theoretic development of his excellently conceived theory of epigenesis proceeds in terms of the causes, and the painstaking application of it to the great variety of animals in which he had observed the phenomena of generation is possible only by the isolation and detection of causes. (Fn.23)

Aristotle has carried through the ages a high repute as a biologist, and (what is probably the same thing) his conception of the problems of biology has continued to the present little changed, for his emphases are among those still prominent in biological studies: the consideration of questions of heredity, sex, nutrition and growth, of adaption to environment, the struggle for existence, and the orderly interrelations of the kinds and functions of animals. Moreover, in many of these problems he developed theories which are still suggestive, such as his explanations of generation, and of variation and heredity. His influence is felt rather more in his statements of the problems of biology and in his general theories than in his specific information (and although that is usually sound and detailed and sometimes even a guide to
modern inquiry, it has suffered from the accidents and progress of history, and has been shown in many instances — as in the case of the organs and organic systems of the human body — to have been defective. His conception of method, however, has been influential only after it has been submitted to radical changes and only as it is inseparable from the organization he set on the subject matter of biology. (Fn.24) Curiously enough, the manner of his influence in physics, in the narrow sense, is similar to his influence in biology, for there too he laid out the main lines of the problems to be considered and set the first consistent significances of the terms which have largely continued to be basic; both in physics and in biology the method he emphasized has all but been ignored. The effect of this divided influence on his reputation, however, was as unhappy in physics as it was fortunate in biology. In general the methodological distinction between the order of nature and the order of science has not been observed: in so far as biological inquiry has continued to rest on an intricate classification of genera and species, the disappearance of that methodological distinction has not affected the influence of Aristotle, but in the physical sciences proper it has led to the contracting and collapsing of almost all the basic distinctions he constructed in those sciences. Each of his terms and principles had several senses which were important in his discussion; in the subsequent history of physics each of them has been reduced to a single sense which would, if applied as it usually is to the interpretation of his physical writings, make simple-minded nonsense of his subtle doctrine.

The influence of Aristotle in physics may be gauged accurately by considering the history of the basic terms, such as matter, motion, cause, principle, necessity, and a dozen others, in which he first stated the problems of physics. It is difficult to trace a relation between the collapsed and simplified meanings attached to those terms after the Renaissance and the concepts and theories treated in Aristotle’s Physics. The key to the influence of Aristotle and to the evolution of physical theories is to be found rather in the doctrines of his On the heavens, for that work attained great prominence in the fourteenth century, and Galileo and his contemporaries continued to discuss the two general problems which are treated in it and which had been the subject of renewed inquiry in the commentaries of the fourteenth and fifteenth centuries: the motion of heavenly bodies, especially as particularized to the earth, and the motion of terrestrial bodies in straight lines, especially as particularized to the fall of heavy bodies. Not only the problems but the particularization of the concepts used in the discussion of the problems can be explained by means of this centering of interest on the subject matter and problems of On the heavens, for in that treatise Aristotle uses each of his important terms in a single meaning. Thus in general, Aristotle distinguishes three kinds of motion and four kinds of change, but in On the heavens all kinds of motion are treated in terms of one kind, local motion; since the sixteenth century motion has almost always meant, except in loose unscientific usage, motion in space. Matter means potentiality for Aristotle, and it may therefore apply to anything, simple or complex, corporeal or incorporeal, in so far as it is considered as a stage relative to further change,
but in On the heavens body and magnitude are the only senses of matter that are relevant to the problems treated; since the sixteenth century matter has meant body or magnitude.

With the reduction of motion to local motion and matter to bodies, potentiality ceases to have the importance Aristotle gave to it in his definition of motion, for it is possible to define motion by means of place (which is shorn of its physical qualities and identified, at least for a period in the history of physics, with mathematical space) and time (which ceases being a measure of motion to assume at least for a time absolute qualities). Once motion is considered in terms of the successive actualities of the successive moments in continuous time, causes too are stretched out in temporal series corresponding to those actualities and moments, and all causes are efficient causes, since actualities are in effect generated in each moment and the only sense of cause by which to account for generation according to Aristotle is the efficient cause. Moreover, by becoming merely ingredients or steps in the "causal series," causes lose their functional variability of meaning relative to things and processes. Some of the great paradoxes of causation which have fascinated modern philosophers may be first discerned in the mixture of contradictory traits which results from merging what Aristotle considered the principles of motion with what he treated as the causes of motion: the cause of motion, thereafter, is sought and identified in the state antecedent to the effect, yet it can be effective only if it is simultaneous with the effect, and "principle" has meanwhile lost all meaning except as the propositions which are set at the head of a science. Moreover, necessity has come to be identified with causation in this narrow sense (whereas Aristotle had identified necessity in physics with the inquiry into antecedents) and since no other meaning of cause remains, causation is opposed to free will, and the contradictions of "determinism" and "indeterminacy" have taken the place of what Aristotle considered merely differences in the direction in which phenomena are viewed, for in his view the antecedents of what has happened are necessary, but the multiplicity of causes makes the future of any single process indeterminate.

In many senses Aristotle's influence in the history of physics has been great, but it was a direct influence during only a short period of the history of physics, and if signs of it are sought, not in problems and in words, but in continuations of his methods for solving problems or of the meanings he gave to words, it would be more nearly true to say that his physics has been all but unconsidered. Scholars and scientists treated Aristotle's physical theories seriously for a short time, then settled down to controversies which centered on the problems formulated in one portion of his physics, rejected what passed current for the Aristotelian solution of those problems, and disposed of the whole of his physics by refuting doctrines which, for the most part, were misconceived and misstated. On the heavens, since it was designed to treat of two fundamentally different sets of problems, resisted reduction to the single scheme of latter-day physics more than most of Aristotle's treatises would have, for his treatment of celestial and terrestrial motion is based on a recognition of palpable differences in those motions, while modern physical theory, prior to the development of relativity physics, is based on the reduction of all such motion to a single cause and a single matter.
Some of Aristotle's principles are taken over in new restricted senses, for he too argues that local motion is fundamental to all other types of change, and he too treats of "first matter" as basic to all elemental transformations. His doctrine as a whole could not survive the refutations which resulted from the simplification of his terms by collapsing the problems of the two parts of On the heavens. If one looks to other characteristics of heavenly bodies than their motions, which are observably different from the motions of bodies near the surface of the earth, no elements are needed other than those which constitute terrestrial bodies, and therefore the "fifth body" or quintessence becomes an unaccountable absurdity. Heavenly bodies can then be treated as Aristotle had treated terrestrial bodies, for their circular motions can be decomposed into two component forces operating in straight lines, and terrestrial bodies can in turn be treated as heavenly bodies, for they are conceived to be in continuous motion, like Aristotle's stars, save as influenced by external forces (whereas Aristotle's converse principle was that bodies remain at rest unless moved by something), and the forces which they exercise on each other are precisely the same as those which operate in the motions of the heavens, to so obvious an extent that the parts of bodies and of atoms have not infrequently been analogized to solar systems. The Meteorology comes closer to treating material causes of the sort which later physicists sought, and if the accident which directed the attention of Renaissance scholars and scientists to the study of On the heavens had turned them instead of the Meteorology, Aristotle might have figured in our histories of science as one of the founders of organic and inorganic chemistry instead of being dismissed as the proponent of a qualitative physics in which unexperienced substantial forms are modified by undistinguishable occult forces.

To trace the influence of Aristotle through the shifts of meanings which the terms of his sciences have undergone is, needless to say, to account for it only dialectically. Such treatment does not touch on the truth or falsity of Aristotle's theories or on the adequacy of the theories that supplanted them except as the significances of the terms in which a theory is expressed are essential to the judgment of its truth or falsity. To raise the question of adequacy or truth would require, as a scientific question, treatment of the problems Aristotle stated in terms of the facts rather than the treatment by default which his doctrines in physics have received, for we still think Aristotle refuted by the recitation of doctrines of Copernicus or Galileo or Newton (since we know that their conclusions contradicted or modified his doctrines) even when the substituted concepts were later contradicted and modified in directions which approach more nearly to the position of Aristotle. Present-day conceptions of time, space, matter, motion, and cause are nearer to those of Aristotle than they have been in four hundred years.

The progress of science during the last few hundred years, moreover, has been influenced by the successive fortunes of a dialectical dispute almost as much as it has been by cumulative acquisition of data and the persistent testing of theories. Aristotle first differentiated the positions opposed in the debate which is still in progress, and the peculiar reception of his own doctrines may be explained most plausibly in terms of the use to
which his adjudication was put by the parties to that debate who continued after him, for both could interpret his resolution as contributing to the maintenance of their respective sides and both could forget his refutation of their doctrines and his resolution of their differences. More recently, in the centuries of the greatest advances in the physical sciences, the two positions have been simply amalgamated, and consequently in recent physics, as in the theology of an earlier period, literal distinctions and differences have been abandoned for analogies and likenesses, and paradoxes which once seemed refutations have been made principles. Whereas Aristotle sought to avoid at the one extreme the reduction of bodies in motion to their material parts, and at the other extreme their reduction to ratios and numerical patterns, the methods that have been tried in physics since the Renaissance have depended on combinations of the two in varying proportions and with varying emphases. The interpretation of Aristotle has been shifted and changed with the progress of science, but the criticism of his physical theories has tended, in modern times, to express a paradoxical vindication of both of the theories which he opposed and refuted: he neglected bodies for forms (and so relied too little on observation and experimentation) and he neglected proportions for substances (and so relied too little on mathematics).

Footnotes to Part 7:

1. Physics ii. 2. 193b35.
2. Metaphysics i. 9. 992b32.
3. Ibid. vi. 1. 1026a27. Cf. Physics ii. 2. 194a19 ff., especially 194b8: "Again, matter is a relative term: to each form there corresponds a special matter. How far then must the physicist know the form or essence? Up to a point, perhaps, as the doctor must know sinew or the smith bronze (i.e. until he understands the purpose of each): and the physicist is concerned only with things whose forms are separable indeed, but do not exist apart from matter. Man is begotten by man and by the sun as well. The mode of existence and essence of the separable it is the primary type of philosophy to define."

4. Metaphysics vi. 1. 1028b25 ff. Aristotle's favorite way of indicating the difference between these two kinds of definitions is briefly to contrast the definition of "snub" (which is bound up with matter since what is snub is a concave or curved nose) with "concave" or "curved" which is independent or perceptible matter. The importance of the distinction between physical and mathematical definitions to his philosophy is therefore indicated graphically in the almost innumerable references to "snub-noses" which dot his works. Cf. above, and ibid. 5. 1030b28; 10. 1035a25; 11. 1037a30; xi. 7. 1064a19; On sophistical refutations 13. 173b10; 31. 181b38; Physics i. 3. 130b31; ii. 2. 194a3; On the heavens i. 9. 278b29; On the soul iii. 4. 429b18; 7. 431b12, etc.

5. Physics ii. 9. 199b54; On the parts of animals i. 1. 639b3; Cf. Metaphysics vii. 7. 1033b15: "Of productions and movements one part is called thinking and the other making — that which proceeds from the starting-point and the form is thinking, and that which proceeds from the final step of the thinking is making." Cf. also ibid. 9. 1034a30: "Therefore substance is the starting-point of all production, as of syllogism. It is from the 'what' that syllogisms start; and from it also we now find processes of production to start. And things which are formed by nature are in the same case as these products of art."
6 Ibid. vi. 1. 1025b4.
7 Physics ii. 1. 192b9 ff. Cf. Metaphysics viii. 1. 1042a6; vii. 2. 1028b5.
8 Physics ii. 7. 198a22. Cf. Metaphysics xii. 1. 1069a30, where the same triple distinction is presented as a triple distinction of kinds of substances.
9 Physics ii. 7. 198a25: "Now the principles which cause motion in a physical way are two, of which one is not physical, as it has no principle of motion in itself. Of this kind is whatever causes movement, not being itself moved, such as (1) that which is completely unchangeable, the primary reality, and (2) the essence of that which is coming to be i.e. the form; for this is the end or 'that for the sake of which'. Hence since nature is for the sake of something, we must know this cause also." Cf. Posterior analytics ii. 11. 94b27, and especially 36: "for nature, in different senses of the term 'nature', produces now for an end, now by necessity."
10 On generation and corruption ii. 1. 329a24.
11 Ibid. ii. 9. 335b7.
12 Meteorology i. 2. 339a27. Cf. ibid. i. 346b16.
15 On the soul ii. 4. 415b12.
16 Cf. ibid. i. 1. 403a1 and ii. 1-4. 412a23. The physical definition of the soul is contrasted to dialectical definitions precisely in its pertinence to the demonstration of properties and functions: "In all demonstration a definition of an essence is required as a starting point, so that definitions which do not enable us to discover the derived properties, and which fail to facilitate even a conjecture about them, must obviously, one and all, be dialectical and futile" (ibid. 403b25).
17 On sense and the sensible i. 436a1: "Having now definitely considered the soul, by itself, and its several faculties, we must next make a survey of animals and all living things, in order to ascertain what functions are peculiar, and what functions are common, to them. What has been already determined respecting the soul must be assumed throughout." Cf. On youth and old age i. 467b13: "We have elsewhere given a precise account of the soul, and while it is clear that its essential reality cannot be corporeal, yet manifestly it must exist in some bodily part which must be one of those possessing control over the members. Let us for the present set aside the other divisions or faculties of the soul (whichever of the two be the correct name). But as to being what is called an animal and a living thing, we find that in all beings endowed with both characteristics (viz. being an animal and being alive) there must be a single identical part in virtue of which they live and are called animals; for an animal qua animal cannot avoid being alive. But a thing need not, though alive, be animal, for plants live without having sensation, and it is by sensation that we distinguish animal from what is not animal."
18 The nature of the problems treated in the On the soul makes that treatise in effect specific to man, but it is one of the assumptions of Aristotle's biological inquiries that the functions of man must be the basis and touchstone of the investigation.
History of animals i. 6. 491\textsuperscript{a}5 and especially 19: "To begin with, we must take into consideration the parts of Man. For, just as each nation is wont to reckon by that monetary standard with which it is most familiar, so must we do in other matters. And, of course, man is the animal with which we are all of us the most familiar." 
Cf. On the parts of animals i. 1. 641\textsuperscript{a}17 where the place of the soul in biological inquiry is considered.

19 History of animals vii. 1. 568\textsuperscript{b}4.

20 Thus the animals are classified in terms of the competition for food and the struggle for existence in the pages which follow the general statement of the principle of classification. (ibid. ix. 1. 608\textsuperscript{a}19): "There is enmity between such animals as dwell in the same localities or subsist on the same food. If the means of subsistence run short, creatures of like kind will fight together. Thus it is said that seals which inhabit one and the same district will fight, male with male, and female with female, until one combatant kills the other, or one is driven away by the other; and their young do even in like manner. All creatures are at enmity with the carnivores, and the carnivores with all the rest, for they all subsist on living creatures..."

21 On the parts of animals i. 1. 641\textsuperscript{a}14.

23 Cf. ibid. ii. 1. 646\textsuperscript{a}24: "Now the order of actual development and the order of logical existence are always the inverse of each other. For that which is posterior in the order of development is antecedent in the order of nature, and that is genetically last which in nature is first. (That this is so is manifest by induction; for a house does not exist for the sake of bricks and stones, but these materials for the sake of the house; and the same is the case with the materials of other bodies. Nor is induction required to show this. It is included in our conception of generation. For generation is a process from a something to a something; that which is generated having a cause in which it originates and a cause in which it ends. The originating cause is the primary efficient cause, which is something already endowed with tangible existence, while the final cause is some definite form or similar end; for man generates man, and plant generates plant, in each case out of the underlying material.) In order of time, then, the material and the generative process must necessarily be anterior to the being that is generated; but in logical order the definitive character and form of each being precedes the material."

24 On the generation of animals i. 17-22, 721\textsuperscript{a}30-730\textsuperscript{b}32.

24 The praise of Aristotle as a biologist has been extravagant and almost universal. Thus Cuvier (Histoire des sciences naturelles, Paris, 1841, I, 132): "In Aristotle everything amazes, everything is prodigious, everything is colossal. He lived but sixty-two years, and he was able to make thousands of observations of extreme delicacy, the accuracy of which the most rigorous criticism has never been able to impeach." Or again, referring to Aristotle's History of animals (ibid. 146): "I cannot read this work without being ravished with astonishment. Indeed it is impossible to conceive how a single man was able to collect and compare the multitude of particular facts implied in the numerous general rules and aphorisms contained in this work, and of which his predecessors never had any idea." The great anatomist and biologist Isidore Geoffroy St. Hilaire expresses a similar
judgment (Histoire générale de règnes organiques. Paris, 1854, I, 18): "He is in every branch of knowledge like a master who cultivates that one only. He reaches, he extends the limits of all the sciences, and penetrates to their very depths." Darwin shares this opinion (Life and letters, London, 1887, III, 252): "Linnaeus and Cuvier have been my two gods, though in very different ways, but they were mere schoolboys to old Aristotle." There are moreover contemporary biologists (like D'Arcy Thompson and William E. Ritter) who profess to follow the lead of Aristotle. A few dissident voices have been equally emphatic, as for example George Henry Lewes (Aristotle: A chapter from the history of science, including analyses of Aristotle's scientific writings, London, 1864), who is particularly violent in denunciation of Aristotle's observations in anatomy and physiology.

8. MORAL AND POLITICAL PHILOSOPHY

Like the theoretic sciences, the practical sciences proceed from first principles. Like those of the physical sciences, the principles of the practical sciences are principles of change and motion, and in practice as in theory, the problem of change turns on the ends to which processes tend and the antecedents which precede or lead to any given stage. (Fn.1) Many of the philosophers who came after Aristotle have used these analogues to prove that both the arts (in their application to productions or "things made") and the practical sciences proper, ethics and politics (in their application to actions or "things done") are theoretic or exact sciences; or that they are branches of physical science or of mathematics; or that physics, politics, and ethics are fine arts, or that art is scientific in operation, or practical in intention as well as in application. Aristotle, however, having noticed the similarities of moral actions and technical or artistic accomplishments to the theoretic inquiries, lays stress upon the crucial differences in their purposes, for the practical sciences are for the sake of doing or making something, not for the sake of contemplating, defining, or knowing it. (Fn.2) They resemble physics in subject matter since they too treat of processes and changes, but physics studies natural motions, while art and action initiate artificial and deliberate motions. They resemble mathematics and physics in method of inquiry, yet in art and action the method of science is used in reverse order. Natural motions and changes, the subject matter of physics, are examined either by inquiring into the end in which such motions eventuate if unhindered, since the properties and functions of a thing are deducible from its definition or end, or by inquiring into the antecedents which must have preceded any accomplished stage of the process, since the material constituents of things are determined by their antecedents. Artificial motions and artificial things are produced in the arts — as virtues, actions, and institutions are inaugurated or preserved in politics — by acquired skills and habits which utilize existent situations as antecedents to ends not yet accomplished.

Moral and technical actions, therefore, cannot be explained by things alone or by natures, as natural motions can, but originate in habits and skills. Neither the action nor its result is susceptible of exact scientific definition; instead, what is done