

III. THE NEW PHILOSOPHY: BRUNO TO DESCARTES¹

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I HAVE been asked to speak to-day on the 'new philosophy' which arose and gradually triumphed in the period between the birth of Bruno in 1548 and the death of Descartes in 1650. I propose to put a fairly wide interpretation on the word 'philosophy', as did all the great thinkers of our period. And I propose to begin by giving a fairly full, though necessarily very imperfect, synopsis of the old philosophy against which the new doctrines reacted and which they superseded. What I shall describe with the name of the 'old philosophy' is the theory of the universe which St Thomas had elaborated on the basis of such knowledge of the works of Aristotle as was available to him. This, for example, is what Descartes would have learnt from his highly intelligent teachers at La Flèche; and it was the intellectual background of all educated men in our period.

It is necessary to devote what may seem to be a disproportionate part of to-day's lecture to the old philosophy, simply because the victory of the new was in the end so complete and has for so long been unchallenged. The conception of the world, of man, and of man's place in nature, which was common to all educated persons at the beginning of our period, is now for most of us a curiosity in a museum which we have never visited. That which was then new and revolutionary has for generations been as familiar and unnoticed as the air which we breathe. As a result we are liable to be unfair to both. The old, taken out of its context, seems to be a mere childish fairy-tale too ridiculous to have ever been sincerely believed; and the new, when explicitly stated, seems so trite and trivial that we cannot understand why the innovators made such a fuss about it. Yet the Thomistic synthesis is one of the greatest achievements of the human mind; and the transition from the old to the new was, in many respects, the most radical change in theory and the most fruitful (for good and for ill) in practice of which we have any record.

Let us begin with the old account of the structure and composition of the Macrocosm. If the position and motion of the sun, the moon, and the planets are observed from the earth night after night over a long period, they are found to form a spatio-temporal pattern whose rhythmic complexity cannot be better summarized than in Milton's words:

Mazes intricate, eccentric, intervolv'd, yet regular—
Then most when most irregular they seem.

¹ A lecture delivered in Cambridge on 4 March 1944 in the series, arranged by the History of Science Committee, on *Science in the Sixteenth and Seventeenth Centuries*.

Now the Greek astronomers set to themselves the problem of describing on a single uniform plan all the observed motions of all the heavenly bodies and of enabling their position at any assigned past or future date to be inferred. The problem was set under the following three conditions: (1) that the earth was to be taken as fixed and other bodies as moving round it, (2) that the only fundamental motion which was to be admitted was to be *circular*, and (3) that every circular motion was to take place with *uniform* speed.

The problem was solved by Hipparchus and Ptolemy by two devices, viz. the theory of *Eccentrics* and that of *Epicycles*. According to the former theory it is not the earth itself, but a point at some distance from it and fixed with respect to it, which is the centre of all the ultimate uniform circulations. According to the latter, each member of the solar system circulates uniformly about a centre peculiar to it; this centre is not at rest, but itself circulates uniformly about another centre, which may in turn be circulating uniformly about another, and so on. Such a series ends with a centre which circulates uniformly about the fixed centre of the cosmos. The ultimate circles with this common fixed centre are called *Deferents*, the others are called *Epicycles*.

By providing each heavenly body with enough epicycles, and by suitably choosing the rates of circulation in its deferent and in each of its epicycles, all the long-term geometrical and kinematic appearances of the heavens can be accounted for to any degree of approximation. Finally, the short-term appearances, which are due to the daily rotation of the earth on its own axis, are explained by supposing that the system of planets, luminaries, and fixed stars rotates as a rigid whole about an axis through the poles of the earth once in every 24 hours.

In itself this scheme is simply a mathematical solution of a mathematical problem. As such, it is a marvellous achievement, and it can be criticized only on the ground that equally effective and much simpler schemes can be devised. This had been done in one way, just before our period, by Copernicus; and it was done in another way during our period by Tycho Brahe; though neither of them could dispense with epicycles. But unfortunately it was treated as a physical theory. The fixed stars were regarded as attached to the inside of a rotating spherical shell which encloses the universe, and the deferent of each planet was associated with a concentric spherical shell rotating on an axis whose axle-boxes are attached to the inside of the starry sphere. For reasons which need not be considered here two additional spheres—the Crystalline Sphere and the Primum Mobile—were assumed to be located outside that of the fixed stars. And for most purposes the theory of eccentrics was often ignored, and the centre of the earth was identified with that of the universe.

According to this theory there is an absolute sense of 'up' and 'down'. Motion *up* is radial motion from the centre of the universe to its circumference; motion *down* is radial motion in the opposite direction. The first rotating shell

above the earth is that associated with the moon's deferent. This divides the universe into a sublunary and a celestial region. It was held that there is a profound difference between sublunary substances and their changes, on the one hand, and celestial substances and their changes, on the other. The stars and planets and their spheres are composed of a superior kind of substance called the *Fifth Element* or *Quintessence*. This is not subject to generation or corruption. The only kind of change of which it is susceptible is perpetual circular motion with constant speed.

So much for the structure of the Macrocosm; now for the composition of the sublunar world. Everything in this is ultimately composed of four elements, to which the names *Earth*, *Air*, *Fire* and *Water* were given. In each of the four elements we can distinguish in thought two correlative factors, viz. substratum and quality. The substratum of all four is the same and is called *Materia Prima*. The quality of each element is conceived in the following way. There are two fundamental pairs of opposite qualities, viz. *hot and cold*, *moist and dry*. Of these *hot* is considered positive as compared with *cold*, and *moist* is considered positive as compared with *dry*. This opinion was, no doubt, based on the fact that germination and growth are fostered by warmth and moisture and checked by cold and drought. Now there are four possible combinations of these qualities, viz. *CD*, *CM*, *HM*, and *HD*. Each such combination characterizes one of the four elements. *Earth* is *materia prima* qualified by coldness and dryness. The corresponding qualities for the other elements are: *Fire*, hot and dry; *Air*, hot and moist; *Water*, cold and moist. There is thus a maximum opposition between *Earth* (*CD*) and *Air* (*HM*), and also between *Fire* (*HD*) and *Water* (*CM*).

It is impossible for any portion of *materia prima* to exist without being qualified by one or other of these four pairs of qualities; and it is equally impossible for these qualities to exist except as qualifying some portion of *materia prima*. *Materia prima* is ingenerable and indestructible, and it occupies continuously the whole sphere of the material universe. It might therefore be compared with the ether of the nineteenth-century physicists or the substantial absolute space of Newton. The elements can be and are transformed into each other and back again, but there is no loss or gain of stuff in this process.

Each of the four elements has a certain natural position in the universe. When it is in that position it rests there quietly. When it is out of that position it has a natural tendency to move radially towards its proper place. The proper place of *Fire* is at the circumference of the universe, and so it tends to move upwards. The proper place of *Earth* is at the centre, and so it tends to move downwards. The proper places of *Air* and *Water* are intermediate; *Air* below *Fire* and above *Water*, and *Water* below *Air* and above *Earth*.

This is as much as I need say about the scholastic physics. I pass now to the metaphysics. This is formulated in terms of three pairs of correlates, viz.

Essence and Existence, Stuff and Form, and Potentiality and Actuality. I will now try to give a rough account of them.

(1) The essence of any substance is that set of interconnected qualities, powers, modes of behaviour, etc. which together constitute its nature and mark it out from other substances. Thus an essence defines a possible substance or species of substances. But there are possible substances, e.g. dragons, which do not exist. So in any actually existing substance we can distinguish in thought the two factors of essence and existence. Now there are two cases of the union of essence and existence to be considered. Generally the connexion between the two factors is contingent. There are lions and there are no dragons; but there is nothing in the essence of the lion to necessitate that there should be lions, and nothing in the essence of the dragon to make it impossible for there to be dragons. This contingent connexion between essence and existence is characteristic of all created substances. On the other hand, we can conceive that there might be an essence or essences which could not fail to be endowed with existence. Any substance whose essence was of this kind would be eternal. It would not just exist throughout unending time; its existence would be altogether non-temporal, and the two factors of essence and existence in it would be distinguishable but logically inseparable, like the equilateralness and the equiangularity of an equilateral triangle. There is one and only one substance of this kind, viz. God; and the existence of every other substance depends on the creative act by which God has instantiated its essence.

(2) I pass now to the notions of *Stuff and Form*. We have already had an instance of them in the theory of the elements. I think that this notion arose from two kinds of empirical fact, and was then generalized into a metaphysical concept. The first fact is that a workman or artist can deliberately impose various forms, of which he already has ideas, on different portions of the same previously undifferentiated stuff. Thus he may make a coin, a kettle, and a ring out of a lump of copper. In all such cases we have first, in the external world, stuff which has not yet received a certain form; and, in the artificer's mind, the idea of a certain form which has not yet been imposed on the stuff. Then, in consequence of his idea and his desire for its external embodiment, a series of changes is set up which ends by the form being imposed on the stuff and a new kind of substance being produced.

The second empirical fact is the reproduction, growth, and self-repair of living plants and animals. Corresponding to each species there is a characteristic shape, size, internal organization, and so on. This constitutes the form of any member of the species. Now each such individual, beginning as an embryo, gradually acquires the adult form of its species by a certain characteristic process of development. Then it maintains this form for a longer or shorter time by continually converting foreign stuff, viz. food, drink, and air, into various tissues, and imposing its own characteristic organization on them.

Eventually it performs these operations less and less efficiently, and finally it fails to do so at all. The body then loses the form of a living plant or animal, and becomes a corpse. This is a mere aggregate of various kinds of informed stuff of a lower order, and it soon breaks down into its components. Generally while an individual is mature it reproduces others which go through the same cycle of growth, maturity, reproduction, decay, and dissolution.

In these biological examples it cannot be said that the concept of the form is present in the mind of an external artificer. Yet everything proceeds as if each individual were striving, and for a time succeeding, and eventually failing to impose the form of its species on the alien materials which it ingests and to propagate it in new individuals which will take its place. In the elements this unconscious striving takes the specially simple form of a tendency in each to move towards its appropriate sphere, if displaced from it, and to rest there.

Now in every substance known to us, including ourselves, there are the two factors of stuff and form. But there can be, and, according to the Scholastics, there are in fact, substances which are pure forms without stuff. The stuff-factor is absent, not only in God, but also in a whole series of created intelligent beings, viz. angels, which rise in a hierarchy above men. In each angel there are the two factors of existence and essence, and these are not merely two inseparable though distinguishable aspects, as they are in God. For angels, like men, are finite created beings; and it is logically possible that God should never have endowed with existence that essence which is the nature of a certain angel, e.g. Gabriel, whom he has in fact created. But an angel, though composite in respect of essence and existence, has nothing in it corresponding to that factor of stuff which is the vehicle of form in all lower creatures. The fact that most of us think of angels only as epicene winged figures on Christmas cards, whilst they play an indispensable part in the Scholastic philosophy, is a typical example of the breach between the medieval and the modern *Weltanschauung*.

(3) The third pair of correlative concepts to be considered is *Potentiality and Actuality*. Every substance has certain powers and dispositions, active or passive, original or acquired, which are characteristic of it. Each of these may remain latent or may manifest itself in a certain number of alternative and mutually exclusive possible ways. The circumstances which prevail at any moment within the substance itself and in its neighbours determine whether a disposition shall manifest itself or remain latent. If they determine that a certain disposition shall be manifested at a certain moment, they determine also which one of its alternative possible manifestations shall then be actualized. The actual history of any substance consists in two kinds of process. (1) The passage of this, that, or another of its dispositions from latency to actuality or vice versa; and (2) the passage from potentiality to actuality and vice versa of this, that, and the other alternative possible manifestation of a disposition which is already in action. The explosion of a mass of nitro-glycerine when

struck would be an example of the first. The change from the solid to the liquid and then to the gaseous state of a mass of wax when the temperature varies beyond certain characteristic limits would be an example of the second. So at every moment in the history of a substance there are the two correlated factors of potentiality and actuality. On the side of actuality we count the manifestations of any of its dispositions which are active at the moment. On the side of potentiality we count any of its dispositions which may be latent at the moment (e.g. the inflammability of petrol that is shut up in a tin), and also all the alternative possible manifestations of each disposition which is active at the moment (e.g. the potential solidity and the potential gaseousness of this petrol, which is now in fact liquid because the temperature is above its freezing-point and below its boiling-point).

Now in respect of actuality and potentiality there are two extremes. At the one end is God and at the other *materia prima*. God has no history. There is therefore no sense in ascribing latent dispositions to him, or in suggesting that he has dispositions which manifest themselves now in one way and now in another according to circumstances. He is therefore described as *Actus Purus*. On the other hand, unformed *materia prima*, which is an ideal limit and not an actual existent, would have no positive powers of its own. It would simply have the passive capacity to receive any and every form. Every substance between these two extremes has at any moment both unmanifested potentialities and powers in action. The general rule is that the higher the position of any substance in the scale of being, the more extensive is the range of its powers and the more intensely and continuously are they manifested. In men and the substances below them there are always many dispositions latent at any moment; and the dispositions manifest themselves in a succession of variegated total states which make up the history of the substance. For example, at any moment most of one's knowledge exists only in a latent potential form; and what is explicitly before one's mind varies from moment to moment, as now one and now another cognitive disposition is brought into action. Here again, there is a characteristic difference between angels and God, on the one hand, and lower created substances, on the other. Angels are neither timeless, like God, nor do they have a variegated life history, like men and the substances below men. In angelic cognition there is nothing comparable to the distinction between waking and drowsing and sleeping, or to that between remembering, perceiving, and anticipating. It is all of the nature of perceiving, though it is not sense-perception but intellectual intuition. Again, there is nothing like our experience of turning attention now to one thing and now to another, or gradually acquiring rational cognition about a subject by a series of deductive steps. Thus the notion of potentiality has a rather special and limited application in reference to angels.

In discussing the notions of Form and Stuff and of Potentiality and Actuality we have met with particular instances of a certain general conception

which is of great importance in the old philosophy. This is the doctrine of the *Hierarchy of Being*. It goes back at least to the Neo-Platonists, and one form of it is very clearly stated by Proclus. This doctrine continually crops up in human thought in one form or another. It appears in the Jewish Cabbalists, in Spinoza, in Leibniz, and in modern times in Bradley. I think that it is derived, *inter alia*, from analogy with the radiation of light from a point-source with decrease of intensity and purity as the distance from the source increases. In the philosophy of St Thomas, God is conceived as in some ways like a point-source of white light. In him there is infinite energy and absolute simplicity. The process of creation is analogous in some respects, though not in all, to the perpetual streaming out of an influence from a centre with diminution of intensity and a consequent loss of purity, growth in complexity, and gradual hardening and coarsening. Thus there emerges a descending hierarchy of being, which is ordered in accordance with the following two rules. (1) That which is higher in the scale can do and experience all and more than all that can be done or experienced by what is lower. (2) The higher in the scale the greater is the activity and intensity of life and yet the greater is the internal simplicity. It is a mark of imperfection to use complicated means to an end. Compare, for example, the fussiness of an unskilled rider or tennis player or fencer with the effortless ease of a skilled agent who accomplishes his purpose efficiently without a single superfluous movement. An angel sees at a glance the truth of complex propositions of geometry and their connexion with the axioms and with other propositions. A man has to argue step by step and to use all kinds of extraneous devices, such as co-ordinates, diagrams, and constructions. In general, items which are dispersed and disorganized in the lower levels of the scale of being are fused and integrated into simple and more efficient units at the higher levels.

Next we must consider the view which the old philosophy took of man, the Microcosm. It recognized more fully than its successors the fact that men are highly paradoxical creatures. We are both sensuous and rational, and the two sides of our nature are indispensable to each other in this life, and yet they constantly conflict. We thus lack the elegant simplicity either of the mere animal or of the angel. The Thomistic explanation is that we come at an important dividing point in the hierarchy of being. We are the lowest kind of intellectual creature and the highest kind of sensitive being. Above us are angels, which are pure intelligences without sensation and without bodies. Below us are mere animals, which are living and sensitive but have no intellectual powers. Our anomalous nature is the sign of our peculiar position in the hierarchy.

According to this philosophy a soul is a form whose stuff is a living body. Neither a soul nor its body is a substance. A body without its soul is a mere aggregate of material substances, a carcass and not an organism. On the other hand, to talk of a soul as a substance which might exist by itself without a body

is like talking of the life of a living organism as something which might exist by itself. This is the whole truth about the relation of soul to body in the case of animals; but there are further complications in the case of men.

There is one profound difference between a man and a mere animal. Both have powers of sensation and sense-perception; but the man has in addition a power which no animal has, viz. that of intellectual cognition. This includes the capacity to think of universals, to know or believe general propositions, to contemplate unrealized possibilities, to see logical connexions, and to draw inferences. Even these powers, and the corresponding acts, belong to the human individual as a single unit composed of soul and body, and not to a certain purely mental part of him called his soul. But the cognitive powers and acts, such as seeing and feeling, which we share with animals take place by means of specialized bodily organs, e.g. the eye and the skin. Intellectual cognition, though it is equally the act of an individual composed of soul and body, does not take place by means of any special bodily organ.

It was held that the fact that a human being has certain cognitive powers which do not depend on a special bodily organ for their exercise leaves open the possibility that each human soul may in some sense survive the death of its body. That this possibility is in fact realized is guaranteed by revelation to Christians. But honest and acute thinkers, like St Thomas, recognized that the theory that the soul is the form of the living body does not fit at all easily into the doctrine of human survival which they accepted as Christians. They admitted and asserted that the condition of a human soul when it is not animating a human body is anomalous and unnatural. The fact that even the higher cognitive processes belong, not to the soul alone, but to the human individual as a unit of soul and body, makes the condition of the soul after the death of its body to be one of suspended activity. St Thomas based on this difficulty an argument in favour of the specifically Christian doctrine of the resurrection of the body and its reunion with the soul at the Last Judgment. It is only after this reunion that the soul is once more in its natural and proper state.

I have now devoted as much of the time at my disposal as I can spare to describing the old philosophy, in which all the men of our period, conservatives and radicals alike, were brought up. We have next to consider why it ceased to give satisfaction. The reaction began in Italy and travelled northward, and there were many causes of it which were not good reasons. At the earlier stages the attack came mainly from scholars and literary men, and it consisted in an appeal from one authority to another rather than an independent attempt to interrogate nature and construct an alternative philosophy. St Thomas's predecessors had had to be content with Latin versions of Arabian translations of Aristotle's works. St Thomas himself had worked with direct translations from the Greek which he had made for him, but he could not read Aristotle in the original for himself. After the revival of learning direct access to the

Greek sources of Aristotle's writings and to the early commentators upon them became easy for scholars. Again, the works of Plato and the Neo-Platonists, and the fragments of earlier Greek philosophers such as Democritus, became available in properly edited texts; so these thinkers could be appealed to as alternative authorities of no less reputable antiquity than Aristotle himself. There was a general stir in men's minds owing to a variety of causes, such as the development of printing and the discovery of the New World. The Thomistic philosophy, which had rightly been regarded as a revolutionary innovation, and had been resisted as such when it was first formulated, was now associated with everything that was stuffy and old fashioned. Lastly, many humanists, with a new-found enthusiasm for correct Latinity, seem to have thought that the fact that the Latin in which the scholastic philosophy was written contained words and constructions unknown to Cicero was enough to condemn it without reprieve.

As a professional philosopher, and not a historian, I shall confine myself to the grounds of dissatisfaction which were also good reasons. We cannot do better than begin with Galileo, who, though not a philosopher in the modern sense of that word, was a man of genius with the most profound physical insight and great experimental and mathematical ability.

The following quotation from Galileo is typical. 'Philosophy is written in that very great book—the Universe—which is always open before our eyes. But we cannot understand it unless we first learn to understand the language and the characters in which it is written. It is written in *mathematical* language, and the characters are triangles, circles, and other geometrical figures, without which means it is impossible, humanly speaking, to understand a word of it.' Accordingly Galileo rejects all such sensible qualities as colour, taste, smell, sound, etc., from the physical world and ascribes to it only extension, figure, position, motion, and mass which can be measured and treated mathematically.

His investigation of the law of falling bodies is the first instance of the kind of combination of reasoning and experiment which is characteristic of modern science. He sees that when a body falls from rest it travels with increasing velocity, and he puts forward the two simplest mathematical hypotheses that he can think of as to the law of this increase. One is that the velocity is proportional to the distance fallen through; the other is that it is proportional to the time which has elapsed since the body began to fall. Before attempting any experiments he tries to deduce by mathematical reasoning the consequences which should be observable on each of these hypotheses. He persuades himself, by reasoning which is in fact fallacious but which could easily be replaced by a valid argument, that the hypothesis that the velocity is proportional to the distance fallen leads to impossible consequences. So he rejects that hypothesis and proceeds to deduce mathematically certain consequences of the alternative supposition that the velocity is proportional to the

time which has elapsed. In doing this he performs quite correctly what is in fact an integration, and reaches the result that the distance fallen should be proportional to the square of the time which has elapsed since the body began to fall.

He now proceeds to test this result by observation, and here both his practical ability and his physical insight are displayed. He has first to devise a method for measuring short lapses of time, and he does this by using a wide vessel with a small hole in the bottom which he can open and shut at will with his finger. He fills the vessel with water; and assumes that, since in a short period the level of the liquid in the vessel does not alter appreciably, the weight of water discharged will be proportional to the time which has elapsed between opening and shutting the hole.

Next he finds that bodies falling freely take too little time for him to be able to test his conclusions accurately by direct experiments on them. So he turns his attention to the case of bodies rolling down inclined planes, where, by making the slope of the plane gentle enough he can make the time of descent long enough to be measured accurately. He finds that his deductions are fully confirmed by observation in such cases.

Then comes another layer of reasoning which displays his physical insight. He argues that the velocity which a body acquires in rolling down an inclined plane must depend only on the vertical distance through which it has descended and not on the slope of the plane. For, as he shows, if this were not so, it would be possible by a suitable system of inclined planes to make a body raise itself above its starting point by the momentum which it has acquired in rolling down from that point. This he sees to be physically impossible. So he can now transfer his results from the case of the body rolling down an inclined plane to that of a body falling freely, which is the limiting case of an inclined plane whose angle is 90° to the horizontal.

Next he makes another application of the principle of continuity. Imagine a body which has rolled down an inclined plane and attained a certain velocity in doing so. Let it then start to roll up another inclined plane. Apart from air-resistance to friction, it will travel upwards, gradually losing velocity, until it stops at the same height as that from which it originally started on the first plane. Now imagine the slope of this second inclined plane made gradually less and less, until in the limiting case it becomes zero. The body will travel farther and farther, and lose velocity more and more slowly, as the slope is diminished. Therefore in the limiting case it will lose no velocity, but will travel on for ever with its original speed. Thus Galileo arrives at a particular case of the Law of Inertia or First Law of Motion.

Galileo now applies his results on falling bodies to the then unsolved problem of the path of a projectile. This seems to me to be one of his greatest triumphs of physical insight and sound reasoning. The body is projected upwards at an angle to the horizontal. Galileo by a stroke of genius sees that this

motion can be regarded as compounded of two motions, one horizontal and one vertical, each of which follows its own laws and goes on independently of the other. The horizontal component continues throughout with unchanged velocity in accordance with the law of inertia. The vertical component follows exactly the same law as if the body had been thrown straight upwards, and, after losing its initial velocity, had then fallen straight downwards. This law has already been established in the way which I have explained. Finally, Galileo shows by geometrical reasoning that a body endowed simultaneously with such a horizontal and such a vertical motion will describe a parabola.

Galileo also did much to undermine the medieval astronomy, considered as a physical theory of the structure and motion of the heavens. His invention of the telescope enabled him to observe irregularities and imperfections on the surface of the moon, and to discover that Jupiter has satellites which are plainly related to it as the moon is related to the earth. He himself accepted the Copernican system, according to which the earth and all the planets move in circles round the sun. He argued against the Ptolemaic system, which I have already described; and against that of Tycho Brahe, according to which the sun circulates round the earth and the other planets round the sun. Remembering the fate of Bruno, who had been burnt alive by the Inquisition in 1600, he very sensibly went through the form of recanting these opinions when threatened with prosecution at the same hands; and so he died at the ripe age of 78 in 1642.

I pass now from Galileo to Descartes. Descartes was an eminent mathematician, and he was the only thinker in our period who was of first-rate importance as a philosopher, not only in the wider sense, but also in the narrower meaning in which we now use that word. In his *Discourse on Method* he has given us a kind of philosophical autobiography which is of extreme interest.

Descartes was brought up at La Flèche in the old philosophy and the old physics. New discoveries were not ignored or despised by his teachers, and he was a brilliant pupil; but he nevertheless felt profoundly dissatisfied. His complaint is that nothing, outside pure mathematics, was proved; everything in natural science and metaphysics was a matter of opinion and controversy. He therefore set himself to seek for a general method by which problems could be attacked and absolutely certain solutions obtained.

Now the search for a general method, and the belief that, if only it could be found, unlimited progress in knowledge and practice would automatically follow, is highly characteristic of the new philosophy. Bacon (1561-1626) and Descartes (1596-1650) speak in the same terms of it and use almost the same metaphors. Both of them hold that there are no great innate differences of intellectual capacity among men; and they compare the right method to a pair of compasses by using which a quite unskilled person can be sure of drawing a more perfect circle than the best artist can draw without one.

Descartes was also convinced that one and the same method is necessary and sufficient for solving problems in every subject.

Starting with these convictions, he naturally began by inspecting and analysing the one subject in which it was admitted that men had reached genuine non-controversial knowledge which was continually growing. This was mathematics, and in particular geometry and arithmetic. If we can discover and formulate explicitly the method by which mathematicians attack and solve their problems, we shall have discovered the general method by which anyone can attack and solve any problem.

But Descartes was at once struck by the fact that even within mathematics there seem to be different methods used in geometry, on the one hand, and arithmetic and algebra on the other. And, although the results are equally certain in both, the solution of geometrical problems seems to depend on the luck or individual insight which enables a geometer to hit on the right construction. Descartes was persuaded that this difference could not be ultimate. He saw clearly that inferences must depend on formal relationships and not on the question whether the terms are geometrical figures or numbers or what not. He was thus led to make one of the most important discoveries in technique that have ever been made, viz. that of analytical geometry. He realized that points can be represented by triads of numbers, that the distance between two points can be represented by a certain algebraical relation between the numbers which represent the points, and that every geometrical proposition must therefore have an algebraical analogue. Conversely, any algebraical relation between numbers can be represented by a geometrical diagram. In geometry, then, he really had found a method which would enable anyone who would follow the rules and had patience to manipulate the symbols to solve any problem however complicated.

We come now to Descartes' treatment of physics. Here, again, his general position was characteristic of the new philosophy in contrast to the old. He rejects the secondary qualities, such as colour, sound, smell, taste, etc., from external nature, and holds that everything must be explained mechanically and mathematically in terms of shape, extension, position, and motion. We have already seen that Galileo had formulated this principle. It is quite explicit in Hobbes, who tried to construct a complete system of mechanistic materialism. And Bacon, who is less radical, nevertheless explains sensible heat, for example, as due to concealed motion of particles, and makes the search for minute structure and process to be an essential part of the true method of science.

But Descartes, being a philosopher in the technical sense, is not content to reject the scholastic physics because it is unfruitful and to adopt the mechanical and mathematical view of nature because it is found to work. He wants to see precisely what was the mistake that the old philosophy made; to explain why we are so liable to make it; to eradicate the last lurking traces of it; and to find

an irrefragable positive basis for the new mechanical physics. This involves him in a very elaborate series of reflexions which I shall now try to trace in rough outline.

Plainly the defect of the old philosophy of nature is, not that it does not rest on experience, but that it accepts the rather superficial data of everyday experience too naïvely and interprets nature too anthropomorphically. The geocentric astronomy, the doctrine of the elements and their oppositions and transformations, and the theory that different elements have their own natural place which they seek to regain, are all transcriptions of readily observable superficial facts and explanations of them in terms of something like willing and striving in the inorganic world. In order to account for colour, weight, heat, and so on it postulates different powers and dispositions in matter, very much as psychologists still postulate various instincts in men and animals. Each of these dispositions is conceived only as the concealed cause of a certain observable effect, and nothing is asserted of them by which they can be connected with each other or from which other observable results can be deduced. All these points had been made also by Bacon before Descartes.

Now it appeared to Descartes after long reflexion that this erroneous view about the external world is bound up with a fundamental muddle about the nature of the human soul and the human body, which the old philosophy had fallen into. Descartes found on reflexion that it was perfectly possible for him to doubt the existence of matter, including his own body, whilst it was utterly impossible for him to doubt the existence of himself and his own doubts and his other experiences. He concluded from this that his self or soul must be something entirely different from his body and must be something which could have existed even if he never had had a body. Hence the scholastic doctrine that the soul is the form of the living organism must be rejected. The soul is a substance of one kind, and the body is a substance of a radically different kind, though in this life a substance of the former kind is most intimately and mysteriously connected with one of the latter kind.

He then proceeds to reflect on the notions of soul and body, or mind and matter, in order to see what is essential and what is only adventitious to each. His conclusion is as follows. The only essential attribute of a mind is the power of cognition. A mind could be conceived which had no feelings or sensations or images or volitions; but it cannot be conceived as being without cognition. Moreover, feeling, sensation, volition, etc., if present, all presuppose cognition. Similarly, the only essential attribute of a bit of matter is extension, which of course carries with it the notion of having some shape, size, and position, and of being capable of motion or rest either as a whole or in its smaller parts. Our concepts of these two fundamental attributes, cognition and extension, are perfectly clear and distinct; and we can see quite clearly that they are mutually exclusive. What is extended cannot think, and what thinks cannot be extended.

Now the notion of extension is not only clear and distinct but is also fruitful. We know with complete certainty very simple axioms about extension, and from these we can pass gradually by perfectly clear reasoning to an unlimited number of more and more complex propositions. Since we have this complete insight into the nature of extension and its logical independence of consciousness, we can see that there can be no contradiction in the notion of a world of extended objects, obeying the laws of geometry and kinematics. Such a world is known to be at least possible. But our ideas of colour, temperature, sound, etc., though impressive and obtrusive, are not intellectually clear. Here, then, we have no such insight. We cannot be sure that the very notion of an independent world of coloured and hot objects, of noises, of smells, and so on, may not involve a latent contradiction. Such a world may then, for all that we know, be a logical impossibility.

Granted, then, that an independent world of extended movable matter, obeying the laws of geometry and kinematics, is a possible existent, can we be certain that it actually does exist? Descartes has two different lines of argument on this question.

(1) He points out that, although we are thinking beings, we are not (as it is logically possible that we might have been) pure intellects. We have sensations, bodily feelings, emotions, and imagery, and not just pure imageless dispassionate cognition. This is a contingent fact, and it has to be explained somehow. Now each of us believes that his mind is very intimately connected with a certain extended material substance, viz. his own body. If this belief were true, we should have an explanation of those contingent peculiarities of human experience which I have indicated; and it is difficult to think of any other explanation. So it is at least a very highly probable hypothesis that there really are those extended material substances which we call human bodies. And if there are these, then there is no reason to doubt that there are others.

(2) Descartes' second line of argument is more fundamental, and it is liable to strike modern readers as peculiar. The fact is that the notion of God, and the proof of God's existence, play an essential part in Descartes' physics and metaphysics. It is a foundation-stone of the whole system, not an ornament which could be dispensed with. Descartes claims to prove the existence of an infinitely wise and powerful creative being by several arguments. Most of them were current in the Scholastic philosophy; but he resuscitates one, viz. the Ontological Argument, which was invented by St Anselm and had been rejected by St Thomas. He also provides a new proof of his own. The essence of this is as follows. Each of us has the idea of an infinitely wise and powerful creative being, and this fact has to be accounted for. He argues that the idea is not a composite one, like that of a mermaid, constructed by combining ideas derived from various objects which we have perceived and by dropping out the limitations which we found in them. The infinity ascribed to God is

positive, not negative; and the unity of the various factors in this idea is intrinsic and is not imposed by us as when we construct the idea of a mermaid from that of a woman's body and a fish's tail. Descartes concludes that our capacity to think of so exalted an object can have been derived from no less a source than a being answering to that idea. Hence God exists, and our innate capacity to form an idea of God may be compared to the mark which an artist puts on a picture or statue to show that it is his handiwork.

Now, since our minds are the work of an infinitely wise and good and powerful maker, we can be sure that all their *original* equipment will be perfect. We shall have no *innate* ideas which are fictitious, and no *genuinely instinctive* beliefs which are false. Error is to be found only in ideas and beliefs which we have acquired in the course of our lives. But we have all acquired many ideas and beliefs so early or so imperceptibly that we are liable to think that we never acquired them at all and that they are innate and instinctive. These are what Bacon picturesquely called *Idols of the Tribe*.

Now the belief that our sensations arise from the action of foreign extended movable objects upon our own bodies is genuinely instinctive and innate. Therefore it must have been implanted in us by God when he created us, and so it must be true. So the existence of a world of extended and movable objects, which surround our bodies and interact with them and with each other, may now be accepted as not merely possible but certain.

But, it may be said, we all ascribe to these objects colour, temperature, etc., as well as extension, figure and motion. Are not these beliefs equally instinctive, and must not they also be therefore accepted as implanted in us by God and thus guaranteed to be true? Here Descartes draws an important distinction. The function of sensations of colour, temperature, taste, smell, etc. is not to supply scientific theoretical knowledge of the nature and laws of the external world as it is in itself. Their only function is to give us biologically useful practical hints about the properties of external things which may make them useful or harmful to us. That is why God gave us the capacity to have sensations of various kinds, including pleasantly and painfully toned organic sensations, and why he implanted in us the belief that every sensible quality is a sign of some correlated quality in the material world. That belief is genuinely instinctive and is true. But the belief that this correlation is identity, that material things are literally coloured and hot and squeaky, is not genuinely instinctive and is nonsensical. It is a confused superstition; which we acquired in childhood, when we accepted uncritically everything that our elders told us and had not clearly recognized the radical distinction and opposition between mind and matter. The Scholastic physics has never grown up. It still ascribes literally to extended, and therefore essentially non-mental, objects qualities which belong only to sensations and therefore can occur only in connexion with minds. That which corresponds in external bodies to the colours, temperatures, etc. which we become aware of when they act on our

sense-organs can be nothing but peculiarities of minute structure or motion in substances which are themselves without colour or temperature.

Descartes' extremely sharp distinction between mind and matter makes the connexion between the soul and the body of an individual into an embarrassing problem for him. On the one hand, a living body is simply an extended substance among others, and no properties may be ascribed to it and its parts except extension, figure, and motion. It is just a highly complicated machine, and all vital phenomena must be explained in purely mechanical terms. On the other hand, a soul is an independent substance which has no spatial characteristics, and therefore it is meaningless to ascribe to it shape, size, position, or motion. Yet we know that in the case of a human being these two utterly disparate substances are somehow intimately yoked together for a time. The fact of rational speech and writing shows that a human mind affects by its thoughts and its volitions some of the movements of its body; and the fact that we have sensations, emotions, and images, shows that certain movements within the body affect the mind. How can we conceive of the bond between two such disparate yoke-fellows? And how can we reconcile the principle of the Conservation of Momentum in the material world with the fact that certain movements, e.g. those of the tongue and the fingers in speech and writing, are determined in part by non-material causes?

Descartes restricts the range of this embarrassment by roundly denying that animals have souls. They are mere machines, and their cries when injured are just the squeaks and clatter of ill-oiled or damaged machinery. But he cannot take this view of men, and all that he can do is to argue that the mind's sole action on the body is to guide and control transformations of momentum within the latter, but neither to increase nor diminish the total quantity of momentum in the material world.

This brings me to the general principles of Descartes' mechanical physics. He is not content to establish the fundamental laws of motion, as Galileo might have done, by putting forward alternative hypotheses in mathematical terms, deducing from each a train of consequences which would be observable under assignable conditions if it were true, and then fulfilling these conditions experimentally and seeing whether the inferred consequences do or do not follow. For this would lead at best to highly probable opinion; and, on such fundamental matters, Descartes can be content with nothing less than knock-down proof and *à priori* knowledge. So God is again called in aid.

Since God is immutable and eternal we must ascribe to his creation only the bare minimum of change that is compatible with observation. Now we know that there is change of the first-order, viz. motion, and therefore that God has deliberately introduced this into the extended world when he created it. But we are entitled to conclude that at the next level, God will have restored stability. The changes will be subject to unchanging *laws*, and the fundamental law of change will be one of *conservation*. So Descartes derives his first law

that the total amount of motion in the world remains at all times the same as it was when God first created it. All changes are simply redistributions of this unalterable original stock of motion. By another bit of *a priori* reasoning Descartes deduces the complete Law of Inertia, i.e. the following proposition: At any moment at which a body is not acted upon from without it will, if at rest, remain at rest; and, if in motion, continue to move with unaltered velocity along the instantaneous tangent to the curve in which it has been moving. I believe that Descartes is the first person to have stated this law fully and correctly. Galileo certainly did neither.

Next, Descartes professes to prove seven laws about the motion of bodies after impact with each other under various initial conditions. Here he is less fortunate. I have worked through all the cases, and I find that some of his laws hold only when the bodies are perfectly elastic, others only when they are perfectly inelastic, and others under no conditions whatever.

It remains to consider Descartes' view of the place of experiments in science. His position is this. We know *a priori* that every natural phenomenon, inorganic or organic, must be capable of a mechanical explanation, and that no other kind of explanation is admissible or intelligible. We can prove *a priori* the fundamental laws of motion; so, although experience is in accord with them, it would be fatuous to base them on experiment. But in the case of a complicated natural phenomenon, e.g. the circulation of the blood, we may be able to think of a number of alternative mechanical explanations, any one of which will explain the observed facts as well as any other. In such cases and in such only experiment becomes important. Although all the mechanical hypotheses under consideration agree in accounting for the natural phenomenon to explain which they were put forward, it will generally be possible to deduce further consequences from each of them; and these will not all be the same under similar conditions. Thus we may be able to devise what Bacon calls 'crucial experiments', which between them will reduce the number of admissible alternatives and perhaps leave only one of them standing.

I will end by attempting very briefly to sum up the strong and the weak points of Descartes' philosophy. He was a man of genius with an extreme dislike for anything misty and confused. So difficulties which were latent in the new philosophy, and which its practical success tended to conceal, stand out clearly in the light of his penetrating and synoptic intellect.

Descartes' absolutely sharp separation of mind and matter, and his denial of all qualities and powers to matter except extension, position, shape and motion was extremely important at the time for the progress of physiology and still more of physics. The sharp separation of mind and body encouraged people to pursue the study of anatomy and physiology as purely physical sciences and to attempt to explain what goes on in living organisms in terms of the mechanical processes which go on in inorganic matter. The extrusion of colour, temperature, and other sensible qualities, and of quasi-psychological

strivings and tendencies, from matter enabled scientists to elaborate a system of mathematical physics, and to explain all that happens in the inorganic world on geometrical and mechanical principles. We have only to compare the sciences in which this has been done with others, like psychology and sociology in which nothing of the kind has proved feasible, to appreciate the enormous importance of this step.

The defects were not at the time so obvious, but by now they are fairly clear.

(1) Even within physics itself Descartes was too much of a purist. In his reaction from the scholastic luxuriance of powers and strivings and faculties he did not allow enough activities and potentialities to matter even for dynamical purposes. Dynamics cannot proceed without the notion of inertial mass in addition to that of extension and motion. And Descartes' system has no room for this. Still less could it have admitted Newton's conception of gravitation, as an ultimate active power in matter. To Descartes this would have seemed a deplorable return of the sow that had been washed to her wallowing in the Scholastic mire of occult qualities and substantial forms.

(2) In biology it is simply not helpful to regard living organisms as automatic machines, and biologists have in fact always used other categories beside those of mathematical physics. Moreover, the sharp division which Descartes necessarily makes between men and animals, and between psychology and biology, was probably in some respects detrimental to the progress of both these sciences.

(3) Lastly, it is quite impossible to believe that Descartes' theory can be ultimately true in philosophy. It is clear and distinct; but distinctly odd and clearly incredible. It leaves on our hands the appearances of colour, sound, temperature, etc., and the various organic sensible qualities. Physics may ignore these for its own purposes; but they are part of the contents of the world, and philosophy cannot ignore them. On such a theory as Descartes', they occupy an ambiguous position between the unextended thinking substances and the extended material substance. Somehow, if he is right, we misperceive external bodies as coloured, hot, etc., and we misperceive our own bodies as qualified by aches, ticklings, and so on. That is we perceive things as having qualities which, if he is right, belong neither to mind nor to matter; and yet there is no third kind of thing for these qualities to belong to.

Descartes' only explanation is that these misperceptions occur in our minds because the latter are so intimately linked with certain portions of matter, viz. our bodies. But this helps not at all. In the first place, the connexion between the human soul and the human body is completely mysterious on this theory. The human soul becomes a kind of Thomistic angel, doomed for a time to haunt a penny-in-the-slot machine, and permitted very occasionally and within very strict limits to interfere with the works. And, secondly, whatever

the nature of this curious and discreditable liaison between minds and certain natural machines may be, it does not explain why the former should perceive the latter as having qualities, such as colour and achiness, which in fact belong to nothing in the universe.

The main lesson to be learned is this. At certain periods in the development of human knowledge it may be profitable and even essential for generations of scientists to act on a theory which is philosophically quite ridiculous. And the success of this procedure may blind people for centuries to the fact that its assumptions are quite incredible if taken to be the whole truth and nothing but the truth.