Thoughts on the Interpretation of Nature
and Other Philosophical Works

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To young persons preparing to study Natural Philosophy[1]

Young man, open this book and read on. If you can manage to reach the end, better books than this will not be beyond you. Since my purpose is not so much to instruct you as to exercise your mind, it matters little to me whether you adopt or reject my ideas, so long as you give them your full attention. Someone more able than myself will teach you how to become acquainted with the power of nature; I shall be content if I have helped you to try out your own powers. And so farewell.

PS. One more word before I take my leave. Always bear in mind that *nature* is not *God*, that a *man* is not a *machine* and that a *hypothesis* is not a *fact*; you may be sure that if you think you have found something here which conflicts with these principles, you will have failed to understand me.[2]

Thoughts on the Interpretation of Nature

Quæ sunt in luce tuemur
E tenebris.
Lucretius, *Liber VI.*[3]

I. Nature is to be my theme. I shall let my thoughts flow from my pen in the order in which things occur to me, to give a better picture of the workings of my mind. These thoughts will consist either of general views on the experimental method, or of particular views on a phenomenon which appears to worry all philosophers these days, and to divide them into two categories. One category consists, it seems to me, of those who have a great many instruments but few ideas; in the other are those who have a great many ideas but no instruments. The interests of truth would best be served if the intellectually inclined finally deigned to associate with their more active colleagues; speculative spirits would then have no need to actually do anything, and those who toil ceaselessly with their hands would do so to some purpose; all our efforts would be united and directed at the same time against the resistance of nature; and in what might be called this league of philosophers, everyone would play the part which suits him best.[4]

II. One of the truths which have been most boldly and forcefully* announced in our own time – one which a good physicist will always bear in mind, and one which will certainly lead to the most beneficial results - is that the domain of mathematicians is a world purely of the intellect, where what are taken for absolute truths cease entirely to be so when applied to the world we live in.[6] This has led to the con-

* See the *Histoire naturelle, générale et particulière*, Vol. 1, *Discours I* (*Note by Diderot*)[5]

clusion that it was the task of experimental philosophy to rectify geometrical calculations, and the logic of this view has been acknowledged even by geometricians themselves. But what is the use of correcting geometrical calculations by experiment? Would it not be quicker to take note of the result of an experiment? It is therefore clear that, without experimentation, mathematics, with its essentially transcendental approach, leads to nothing precise; it amounts to a kind of generalised metaphysics,[7] in which bodies are stripped of their individual qualities; and there would still be a need for someone to write a great work with the title *The Application of experimentation to geometry* or *A Treatise on the aberration of measurements.*

III. I do not know whether there is any connection between having an aptitude for gambling and having a mathematical turn of mind; but games of chance and mathematics have a great deal in common. Setting aside the uncertainty of fate on the one hand, or comparing it with the inaccuracy of abstraction on the other, a game of chance can be considered as an indeterminate series of problems to be resolved according to a certain set of conditions. There is no aspect of mathematics to which this definition is inapplicable; and a mathematician's ideas have no greater reality in nature than those of the gambler. Both are a matter of convention. When geometricians decried metaphysicians, they never dreamt that their entire discipline was nothing more than metaphysics. Someone once asked: 'What is a metaphysician?' A geometrician replied: 'A man who doesn't know anything.' It seems to me that chemists, physicists, natural scientists and all those devoted to the experimental method, who are no less adventurous in their judgements, are about to avenge metaphysics and to define geometricians in the same way. 'What, they say, is the good of all these profound theories about the heavenly bodies, all these vast calculations dealing with rational astronomy,[8] if they do not save Bradley or Le Monnier[9] the trouble of observing the heavens?' And I say: 'A geometrician is fortunate if his absorbtion in the study of the abstract sciences has not blunted his appetite for the fine arts; if he is as familiar with Horace and Tacitus as with Newton; if he can discover the properties of a curve and enjoy the beauties of a poet; if his mind and works will never date, and if he is honoured by every academy!' He will never fall into obscurity, and need not fear outliving his fame.[10]

IV. We are at the dawn of a great revolution in science. To judge from the inclination men's minds would appear to have for ethics, literature, natural history and experimental physics, I would almost go so far as to assert that, within the next hundred years, there will hardly be three great geometricians in Europe. This branch of science will just cease at the point where Bernoulli, Euler, Maupertius, Clairaut, Fontaine and d'Alembert have left it.[11] It will stand like the Pillars of Hercules and no-one will pass beyond.[12] Their works will endure in centuries to come, like the Egyptian pyramids, massive and laden with hieroglyphics, an awesome picture of the might and resources of the men who built them.

V. At the dawning of any new science, all men's minds are of course drawn to it as a result of the high esteem in which society holds inventors, the desire to familiarise oneself with something which is much discussed, the hope of distinguishing oneself by some discovery, and the ambition to share the honours with men of worth. Any new science is instantly cultivated by many people of different types. These may be worldly individuals, who find it difficult to live with their own idleness, or fickle minds aspiring to build themselves a reputation in a science which is fashionable, having already failed to do so in other branches of science which they have now abandoned; some make a career of it and others take it up out of inclination. So much concerted effort combines to make this branch of science achieve its potential quite quickly. But as its boundaries are stretched ever further, the esteem in which it is held diminishes. Only the most outstanding exponents are accorded any consideration. And then the crowd thins out; no-one sets off then for a land where fortunes are rarer and harder to make. Science is then left only with mercenaries who earn a crust from it, and a few men of genius to whom it continues to bring honour long after its prestige has faded, and eyes have been opened to the futility of their work. Their accomplishments are still regarded as *tours de force* which do honour to mankind. That, in brief, is the history of geometry, and of every branch of science when it ceases to instruct or to delight. Even natural history is no exception.[13]

VI. When we compare the infinite number of phenomena in nature with the limitations of our own intelligence and the frailty of our organs,[14] how could we ever expect to discover – in view of the

slowness of our work, the long and frequent interruptions which it suffers, and the scarcity of creative spirits – anything but a few broken, isolated parts of the great chain which links everything together.[15] Even if experimental science continued to work for century after century, the materials which it accumulated would eventually have become too great to fit into any system, and the inventory of them would still be far from complete. How many volumes would be needed to encompass just the terms intended to designate different sets of phenomena, once these phenomena had been ascertained? How long will it take for the language of philosophy to be complete? And, even if it were complete, what man could possibly master it? And if, as an even clearer sign of his omnipotence than the wonders of nature, the Almighty had deigned to sketch out the mechanisms of the universe on sheets inscribed in his own hand, is this great tome likely to be more intelligible to us than the universe itself? And how many of its pages could have been understood by the sage who, even with all his great intellectual powers, was not sure that he had grasped the chain of reasoning which had led a geometrician in the past to determine the relationship between a sphere and a cylinder? For us, these pages would represent a fairly good yardstick of our breadth of mind, but an even better satire on our vanity. We could say: Fermat reached this page or that,[16] and Archimedes went a few pages further. But what is our purpose? To create a work which can never be accomplished, and which would be far beyond man's intelligence if it were ever completed. Are we not even more insane than the first inhabitants of the plain of Sennar?[17] We know the infinite distance between earth and the heavens, and yet we never tire of trying to raise the tower. But can we assume that the time will never come when we pocket our pride and abandon the project? Does it seem likely that, housed as he is in cramped and uncomfortable conditions here on earth, man would persist in building a palace in which he could live beyond the atmosphere? And even if he did persist, would he not be halted by the babble of languages, which is already all too noticeable and too troublesome in natural history?[18] It is also true that the idea of 'usefulness' sets boundaries on everything. The criterion of usefulness is about to place limits on geometry, and in a few centuries from now, it will do the same for experimental science. I estimate that this field of study will last for some centuries yet, because it has an infinitely broader spectrum of use than any abstract science, and because it is indisputably the basis of everything which we know for certain.

VII. So long as something exists only in the mind, it remains there as an opinion, or a notion which may be either true or false, and which can be accepted or contradicted. It becomes meaningful only when linked to things which are external to it. This linkage is achieved either by an uninterrupted series of experiments, or by an uninterrupted line of reasoning, one end of which is rooted in observation and the other in experimentation;[19] or else by a series of experiments scattered at intervals in a reasoned argument, as weights may be attached along a thread held by its two ends. Without these weights, the thread would be at the mercy of the slightest breath of air.

VIII. Concepts which have no foundation in nature may be compared to those Northern forests where the trees have no roots. It needs nothing more than a gust of wind, or some trivial event, to bring down a whole forest of trees – and of ideas.[20]

IX. Men have scarcely begun to realise how rigorous are the laws governing enquiry into the truth, and how few are the means at our disposal. The whole enterprise comes down to proceeding from the senses to reflection, and from reflection back to the senses: an endless process of withdrawing into oneself, and re-emerging. This is how bees work. We will have foraged in vain if we do not return to the hive loaded with beeswax. All this wax will have been accumulated in vain, unless we know how to make honeycombs.

X. Unfortunately, however, it is quicker and easier to commune with oneself than to consult nature. That is why reason tends to remain cloistered, whereas instinct wants to reach outside itself. Instinct never ceases to watch, to sample, to touch and to listen; there may be more experimental science to be learnt from studying animals than by following the courses given by a professor. There is no artifice in what they do. They set about achieving their purposes, careless of what is around them; if they do take us by surprise, that is not their intention. Astonishment is the first reaction to any great phenomenon; it is the task of philosophy to dispel it. The purpose of a course in experimental philosophy is to send the listener away better informed, not stunned. To pride oneself on natural phenomena, as though one had invented them oneself, would be to imitate the stupidity of an editor of the *Essais*, who could never hear the name of Montaigne without blushing.[21] There is a fundamental lesson which there is often occasion to teach:

the recognition of one's own inadequacy. Would it not be better to win the confidence of others by frankly admitting 'I simply do not know', than to keep babbling on and cover oneself with embarrassment by endeavouring to find explanations for everything? Anyone who openly admits his ignorance of something he knows nothing about makes me more inclined to believe what he does try to explain to me.[22]

XI. Astonishment often arises from imagining several extraordinary events when only one has taken place, and from imagining as many discrete occurrences in nature as there are phenomena, whereas perhaps there has never been more than a single act of nature. It further appears that if nature had been obliged to produce more than one such act, the differing results of these acts would have remained separate; moreover, there would be sets of phenomena unrelated to one another, and the common connecting chain, which philosophy takes to be continuous, would be broken at several points. The total separateness of an individual fact is incompatible with the concept of a whole, and without that philosophy would cease to exist.[23]

XII. It would appear that nature has chosen to use the same mechanism in an infinite number of different ways.* She never abandons one type of creation before replicating that genus in all its possible variations. If we consider the animal kingdom, and observe that, among the quadrupeds, every single one possesses functions and bodily parts - especially internal organs - fully resembling those of any other quadruped, is it not easy to believe that in the beginning there was only a single animal which served as prototype for all the others, and that all nature has done is to lengthen, shorten, alter, multiply or eliminate certain organs?[24] Imagine the fingers of the hand joined together, with the substance of the nails so extended and thickened that it engulfs and covers the whole body; then, instead of a human hand, you would have a horse's hoof.† When we observe the successive outward metamorphoses which take place in this prototype, whatever it may be, pushing one realm of life closer to another by

* See *Histoire naturelle,* Tom. IV, *Histoire du Cheval,* and a little work written in Latin with the title *Dissertatio inauguralis metaphysica, de universali Naturæ systemate, pro gradu Doctoris habita,* printed in Erlangen in 1751, and brought to France by Mr de M*** in 1753 (*Note by Diderot).*

† See *Hist. nat. gén et part.* Tom. IV. *Description du Cheval* by Mr Daubenton (*Note by Diderot).*

imperceptible stages, and populating the regions where these two realms border on each other (if they can be referred to as 'borders' in the absence of any true divisions); and, populating, as I said, the border regions of the two realms with vague, unidentifiable beings, largely devoid of the forms, qualities and functions of one region and assuming the forms, qualities and functions of the other; who, then, would not be persuaded that there had never been more than one single prototype for every being? But whether one accepts this philosophical conjecture as true, like Doctor Baumann.[25] or rejects it as false, in common with Monsieur de Buffon, no-one will deny that it should be adopted as an essential hypothesis for the advancement of experimental physics, of rationalist philosophy and for the discovery and explanation of phenomena which depend on being organised. Obviously, nature could never have preserved such a degree of similarity amongst its constituent parts, and introduced such variety in the forms it adopts, without frequently bringing out something in one organism which has been suppressed in another. In this, nature resembles a woman who likes to dress up, and whose different disguises, exposing first one part of herself and then another, give some hope to her ardent admirers that they may one day get to know the whole person.[26]

XIII. It has been found that the same seminal fluid exists in both sexes.[27] The parts of the body containing this fluid are now known. The singular alterations which occur in certain female organs when the woman is hard pressed by nature to seek a male have been noted.* In the coming together of the sexes, when one compares the signs of pleasure on either side and has ascertained, by clear and characteristic spasms, that rapture is achieved on both sides, one could never doubt that comparable emissions of seminal fluid have taken place. But where and how does this emission take place in a woman? What becomes of the fluid? What pathway does it take? This will be known only when nature itself, which is not always so mysterious in all places and at all times, reveals itself in another species. This will probably happen in one of the following two ways: either the shape of these organs will become more pronounced, or else emission of the fluid will manifest itself at its place of origin, and all along its pathway, by its remarkable abundance.[28] Anything clearly seen in one being will

* See the *Histoire naturelle,* and especially the *Discours sur la génération* (*Note by Diderot).*

not fail to become apparent in another being of a similar type. The empirical approach to the physical sciences teaches us to identify lesser examples in greater phenomena, just as the rationalist approach teaches us to recognise greater organisms from lesser examples.

XIV. I picture the vast realm of the sciences as an immense landscape scattered with patches of dark and light. The goal towards which we must work is either to extend the boundaries of the patches of light, or to increase their number. One of these tasks falls to the creative genius; the other requires a sort of sagacity combined with perfectionism.

XV. We have three approaches at our disposal: the observation of nature, reflection and experimentation. Observation serves to assemble the data, reflection to synthesise them and experimentation to test the results of this synthesis. The observation of nature must be assiduous, just as reflection must be profound, and experimentation accurate. These three approaches are rarely found together, which explains why creative geniuses are so rare.[29]

XVI. The philosopher often grasps the truth in just the same way as an inept politician, noticing an opportunity, asserts that, like the side of a head which has no hair, it simply cannot be grasped, at the very moment when the experimenter's hand chances upon the side which has some hair. Yet it has to be admitted that, amongst these experimenters, some are very unfortunate: one might devote a lifetime to observing insects without seeing anything new, while another, casting a passing glance at them, might discover the polyp or the hermaphrodite aphid.[30]

XVII. Has the universe lacked men of genius? Not at all. Is the problem then their failure to study and reflect? Even less so. The history of science is studded with famous names; the earth's surface teems with memorials to our work. Why, then, do we have so little certain knowledge? Why has it been the destiny of science to make so little progress? Are we fated always to be nothing but children? I have already given my answer to these questions. The abstract sciences have too long – and too fruitlessly – occupied the best minds; either we have failed to study what needed to be known; or else we have failed to apply selectivity, opinions or method to our studies. Words have proliferated endlessly and the knowledge of things has lagged behind.[31]

XVIII. The right approach to philosophy, both in the past and now, would have been to apply the understanding to what has been understood; to apply understanding and experimentation to the senses; the senses to nature, and nature to the investigation of the instruments to be used; and finally, to employ these instruments for researching into and perfecting the arts, which should be set before the public to teach people to respect philosophy.

XIX. There is only one way of truly recommending philosophy in the eyes of the common people, and that is by associating it with usefulness.[32] The common man always asks the question: 'What's the good of that?' and one should never find oneself in the position of having to answer 'None.' He does not realise that what gives enlightenment to the philosopher and what serves the common man are two very different things, since the philosopher's mind is often illuminated by something harmful and clouded by something useful.[33]

XX. Facts themselves, of whatever type, are the philosopher's true wealth. But one of the abiding convictions of rationalist philosophical thought is that anyone incapable of counting his coins will hardly be any richer than the man who has only a single coin.[34] Unfortunately, the rationalist school of thought is much more concerned with drawing together and connecting the facts it possesses than in accumulating new ones.

XXI. Collecting facts and making associations between them are two very onerous occupations, so philosophers have divided these two tasks up between them. Some spend their lives collecting materials, labouring hard and usefully; others – vainglorious architects as they are – hasten to make use of their work. But virtually all the edifices of rationalist philosophy have been overturned with the passage of time. Sooner or later the dusty labourer will drag up, from the depths where he has been blindly delving, the piece which will fatally undermine the structure erected by force of intellect; it will crumble, leaving only a haphazard mass of rubble, until such time as another bold spirit undertakes some new combination of materials. The systematic philosopher is fortunate if, like Epicurus, Lucretius, Aristotle and Plato in the past, he is endowed by nature with a vivid imagination, great eloquence and the skill to express his ideas with striking and sublime imagery! The structure he has erected may well collapse one

day; but his statue will remain standing amongst the ruins and a stone breaking away from the hillside will not shatter it, because it does not have feet of clay.[35]

XXII. The intellect has its preconceptions just as the senses have their own uncertainty, the memory its limits, the imagination its pale flickerings, and instruments their shortcomings.[36] Phenomena are endless; their causes are hidden and their pattern is, perhaps, transitory. All we have for dealing with such obstacles, both those within us, and those imposed by nature from without, is the slow accumulation of experience and our limited powers of reflection. Such are the levers with which philosophy intends to make the earth move.[37]

XXIII. We have identified two types of philosophy – one is empirical and the other rationalist. One of the two goes blindfolded, always groping its way, grasping everything which comes to hand and finally encountering precious things. The other assembles these precious materials and attempts to fashion them into a flaming torch; but this would-be torch has, until now, served less well than the gropings of the rival camp - and this is as it should be. Experimentation moves endlessly, and is forever active; it devotes as much time to seeking out phenomena as reason spends on seeking analogies. Experimental science does not know what its work will produce and what it will not, but it nonetheless labours without respite. Rationalist philosophy, in contrast, weighs up the alternatives, pronounces on them and stops there. It boldly states that '*light cannot be split*'; meanwhile the experimental philosopher merely listens without rejoinder throughout the centuries and then, suddenly, he brings out the prism, with the words '*light can be split*'.[38]

XXIV. Here is an outline of experimental science.[39]

In general, experimental science deals with the existence, the properties and the use of the objects it studies.

EXISTENCE encompasses their *past history, description, generation, preservation* and *destruction.*

Their *past history* concerns their location, the process of importing and exporting them, their cost, the preconceptions surrounding them, etc.

Their *description*, both internal and external, includes all observable properties.

Generation moves from their earliest origins up to the state of perfection.

Preservation uses every means of maintaining them in that state.

Destruction includes everything between the state of perfection and the last known point of *decomposition* or *disintegration, dissolution* or *reconstitution.*

QUALITIES may be general or individual.

Those which I call *general* are common to all things and only vary in quantity.

Those which I call *individual* are qualities which make a thing what it is; they apply either to the whole being, or else to one of its parts or to its decomposed state.

The concept of USE encompasses *comparison, application* and *combination.*

Comparison is based on resemblance or differences.

Application should be as wide and varied as possible.

Combination is either analogous or odd.

XXV. I use the words *analogous* or *odd* because everything produces its effect in nature, from the most extravagant to the best planned of experiments. Experimental science sets out without preconceptions and is always happy with whatever comes along, whereas the rationalist school is always well-prepared with ideas, even when its suppositions are not borne out.

XXVI. Experimental science is an innocent field of study, and scarcely requires the soul to prepare itself at all.[40] The same cannot be said of other schools of philosophy, the majority of which promote an appetite for conjecture which experimental philosophy eventually suppresses. Sooner or later, the appetite for wild conjecture begins to pall.

XXVII. A taste for observation may be instilled into anyone, although a taste for experimentation, it would seem, should be instilled only in those who are well off.

Observation requires nothing more than the normal use of the senses, whereas experimentation demands continual expenditure. It would be desirable for men of rank to add this ruinous pursuit to the many other – less respectable – ones they have devised. All in all, it would be better for them to be impoverished by a chemist than stripped of everything by tradesmen; better to be engrossed in

scientific experiment, which would afford occasional amusement, than stirred by the shadow of an elusive pleasure, which they never cease to pursue. I would readily give the same advice to thinkers of limited means with an inclination for scientific experiment as I would to a friend of mine if he were tempted to enjoy a beautiful courtesan: *Laïdem habeto, dummodo te Laïs non habeat.*[41] And I would give the same advice to anyone with sufficient breadth of mind to imagine systems, and sufficiently wealthy to be able to test them by experimentation: Yes, by all means have a system, but do not let yourself be ruled by it: *Laïdem habeto.*

XXVIII. The good effects of scientific experiment may be compared to the advice of a father whose dying words to his children were that a treasure was buried in his field, but he did not know exactly where. His children set about digging the field; they did not find the treasure they sought, but they reaped a rich harvest that season which they had not expected.[42]

XXIX. The following year, one of the men's children said to his brothers: 'I have carefully inspected the land which our father left to us, and I believe I have discovered the site of the treasure. Listen: this is how I have worked it out. If the treasure is buried in the field, there must be certain signs within it which mark the place; well, I have noticed some unusual markings near the corner which faces east: the ground looks as though it has been disturbed. We have already made sure, through the work we did last year, that the treasure is not to be found near the surface; therefore it must be buried deeper. Let us take up our spades here and now and dig until we come to the miser's underground hoard.' The brothers all set to work, carried away less by the force of reason than by a desire for riches. They had already dug deep without finding anything; their hopes were beginning to fade and mutterings were heard. Then, one of them, seeing some shining fragments, formed the idea that he had come across a mine. It was indeed a mine – a lead mine which had been exploited in the past. They worked the mine, which gave them a plentiful yield. The experiments suggested by the observations and systematising notions of the rationalist school of thought sometimes produce a similar outcome. That is how chemists and geometricians, obsessed with solving problems which are perhaps insoluble, came to make discoveries more important than the solution itself.

XXX. The long-established habit of conducting experiments gives even the lowliest practitioners a feeling of knowing what is about to happen which is akin to inspiration.[43] It is entirely up to them whether they make the same mistake as Socrates – of calling it their 'familiar spirit'. Socrates was so unusually experienced at assessing men and weighing up circumstances, that even in the most delicate of situations an accurate and rapid process occurred secretly within him that was followed by a prediction which was never belied by events. His judgement of individuals was based on feeling, in the same way as men of taste judge works of the intellect. The same applies to experimental science and to the instinct of our great practitioners. They have seen nature at work so frequently, and from so close at hand, that they can fairly accurately guess at her likely course, even if they decide to provoke her by embarking on the oddest type of trials. The greatest service they can perform for those they initiate into empiricism is, therefore, not so much to introduce them to procedures and results as to imbue them with a propensity for divination, enabling them to 'scent', so to speak, unknown procedures, fresh experiments and hitherto-undiscovered results.

XXXI. How is this propensity passed on? Anyone endowed with it should look within himself to get a clear picture of it, replace the 'familiar spirit' by clear and intelligible concepts, and then develop them for the benefit of others. Should he should find, for instance, that it is 'a facility for supposing or perceiving contrasts or analogies which is rooted in a practical knowledge of the physical properties of subjects taken in isolation, or of their reciprocal effects when taken in combination'; he would extend this idea, supporting it with innumerable facts occurring to his memory. This would be a faithful account of all the apparently extravagant thoughts which have run through his mind. I use the word 'extravagant' – for how else could one describe such a sequence of conjectures, founded on contrasts and resemblances so remote and so imperceptible that the dreams of a sick man appear neither more strange nor more disjointed in comparison?[44]

Sometimes there is not a single proposition that cannot be disputed, either as it stands or in relation to what precedes or follows it. It forms such a precarious whole, both in its suppositions and in its consequences, that it has often been rejected as a basis for observations or experiments.

EXAMPLES

XXXII. *Conjectures, first series*

1. There is a certain body known as a mola.[45] Some maintain that this singular body is engendered in the female without the assistance of the male. However the mystery of generation may be accomplished, both sexes are certainly involved. Could the mola not be an assembly, either of every element emanating from the female in the production of a male, or of all the elements emanating from the male in his different approaches to the female? Could these elements which are quiescent in the male, but widespread and sustained in certain females with a hot temperament and a vivid imagination, not be fired and stirred into activity? And could those elements which are quiescent in the female not be activated either by an arid and sterile presence, and by seemingly barren and purely carnal movements of the male, or else by the violence and the repression of desires induced by the female; could they not then leave their storage site for the womb where they remain, and combine of their own accord? Could the mola not be the product of this combination of elements emanating from the female alone, or those originating just from the male? If the mola results from a combination such as I envisage, however, the laws governing this combination will be just as invariable as the laws of generation itself... The organisation of the mola will therefore remain invariable.[46] If we were to take up a scalpel and perform dissections on these molæ, we might even discover some which bore traces associated with the difference between the sexes. This might be described as the art of proceeding from the relatively unknown to the completely unknown. It is an irrational form of behaviour found to a surprising degree in those who have acquired, or who possess naturally, a gift for the experimental sciences; dreams of this sort have led to a number of discoveries. It is this sort of guesswork which should be taught to learners – if, indeed, it can be taught at all.

2. However, if it is discovered in the course of time that the mola is never engendered in the female without the involvement of the male, then a number of new and far more convincing conjectures can be formulated on the subject of this singular body. The web of blood-vessels which we call the placenta is known to be a mushroom-shaped segment of a sphere, adhering by its convex area to the womb throughout pregnancy, with the umbilical cord serving as a stalk; it

comes away from the womb during the contractions of childbirth; its surface is smooth in a healthy woman who has had a successful delivery. In its generation, its bodily conformation and its behaviour, a living being is never anything but what the constraints of its existence, the laws of motion, and the universal order of things determine that it shall be; should this segment of a sphere – which appears to adhere to the womb only through being placed in contact with it – happen gradually to come away at the edges from the start of pregnancy, and continue to do so at a rate directly proportional to its increase in volume, it occurred to me that these edges, once free of any attachment, would draw closer and closer together, and assume a spherical shape. The umbilical cord, tugged by two opposing forces – one caused by the convex and detached edges of the segment, which would tend to shorten it, and the other by the weight of the foetus, which would tend to lengthen it – would then be much shorter than under normal conditions. A time would come when these edges would meet and knit together, forming a type of ovum, in the centre of which a foetus, as abnormal in its organisation as in its production, would be found, obstructed, constricted and suffocated. This ovum would feed until the small surface area still connecting it came away entirely under its weight, and it fell into the womb unattached, whence it would be ejected by being laid, rather as a hen lays an egg (an object to which the ovum, at least by its shape, has some similarity). If these conjectures could be tested in a mola, and if it were nonetheless demonstrated that this mola is engendered in the female without any assistance from the male, it would then clearly follow that the foetus is formed entirely in the female and that the male only becomes involved at the development stage[47].

XXXIII. *Conjectures: second series*

Let us assume that, as one of our greatest thinkers claims,[48] the earth has a solid vitreous core, and that this core is coated with dust; we may be sure that, in accordance with the laws of centrifugal force (which tend to push free bodies towards the equator, and to give the earth the shape of a flattened sphere), this dust would settle in finer layers at the two poles than at any other latitude; the core may be devoid of dust at the two ends of the axis, and to this characteristic should be attributed the direction in which a magnetised needle turns, no less than the aurora borealis (which is probably no more than an electrical current).[49]

There are good reasons for believing that magnetism and electricity arise from the same causes.[50] Why should they not be effects of the earth's rotational movement, and of the energy given off by the matter of which the earth is composed, combined with the action of the moon? High and low tides, currents, winds, light, and the movement of the free particles of the earth – and possibly even the motions of the entire earth's crust over the core, and so on – produce constant friction in innumerable ways. Over the centuries, the effects of observable and continuous causes achieve a great deal. The earth's core is a vitreous mass; its surface is covered merely with glass débris, sand and vitreous matter. Glass is, of all substances, the one which produces the greatest quantity of electricity by friction. Could the total mass of all the electricity on earth not be the result of all the friction taking place either at the surface of the earth or at its core? But it may be assumed from this general cause that a few attempts will be enough to deduce a particular cause which will create between two great phenomena – I refer to the position of the aurora borealis and the direction of a magnetised needle – a link similar to the connection observed between magnetism and electricity; this could be done by magnetising needles by means of electricity alone, without using a magnet. These notions can be either accepted or denied, since they only exist in my mind as yet. It is experimentation which will validate them, and the task of the empirical scientist is to devise experiments which will finally either separate or bring together different phenomena.[51]

XXXIV. *Conjectures: third series*

Electrical matter diffuses an observable sulphurous odour at sites where electricity is generated; did chemists not have the right to investigate this property? Why did they not test fluids with the highest possible electrical charge, using all the means at their disposal?[52] As yet, we do not even know whether electrolysed water dissolves sugar more or less rapidly than ordinary water. The heat of a furnace is known to produce a considerable increase in the weight of certain materials such as calcinated lead;[53] if electrical heat constantly applied to this calcifying metal were to increase this effect further still, could a new analogy then not be drawn between electrical heat and ordinary heat? This extraordinary type of heat has been tested to see whether it could enhance existing remedies, and make a substance more effective, or a topically-applied treatment more active; but were these

trials not abandoned too soon? Why should electricity not modify the formation and properties of crystals[54]? Any number of conjectures are waiting to be formed in the mind - and to be confirmed or refuted by experiment! *See the next paragraph.*

XXXV. *Conjectures: fourth series*

Do most meteorites, will-o'- the-wisps, exhalations, shooting stars, natural or synthesised phosphorus, and rotting, luminous wood have any causes other than electricity?[55] Why should the experiments needed to determine the question not be conducted on these types of phosphorus? Why is there a reluctance to establish whether air, like glass, is an electrical body in itself - that is, a body which needs nothing more than to be rubbed and struck in order to be electrolysed?[56] Who can tell whether air charged with sulphurous matter may be found to be more or less electrically charged than fresh air? If a metal rod offering a wide surface area is swung round at high speed in the air, it will be possible to determine whether the air is electrically charged, and how much electricity the rod has received from it. If, in the course of the experiment, sulphur is burnt along with other materials, those which increase, and those which reduce, the electrical quality of the air will then be identified. The cold air at the two poles may be more susceptible to electricity than the warm air of the equator; and, since ice is electrical and water is not,[57] who can say whether the enormous amount of permanent ice which is amassed at the poles - and which perhaps moves across the vitreous core, which is more exposed at the poles than elsewhere - might not account for the phenomena of the magnetised needle and the onset of the aurora borealis, both of which also appear to depend on electricity, as we suggested in the second series of these conjectures?[58] By observation, one of the most generalised and powerful forces of nature has been identified; it is now the task of experimentation to discover its effects.

XXXVI. *Conjectures: fifth series*

1. If the string of a musical instrument is taut, and an obstacle which weighs very little divides it into two unequal sections in such a way that the vibrations from one of these sections can be communicated to the other without any hindrance, we know that this obstacle causes the greater of the two sections to divide into vibrating segments, so that the two sections of the string sound in unison, and the vibrating segments of the larger section each fall between two fixed

points.[59] The resonance obtained in this way does not cause the division of the larger section, while the unison between the two sections is merely an effect of this division. It therefore occurred to me that, if a metal rod were to be substituted for the string of the instrument, and struck with great force, bulges and nodes would then form all along it; the same would be true of any elastic body, whether capable of producing sounds or not; this phenomenon, which is thought to be peculiar to vibrating strings, occurs to a greater or lesser extent whenever there is any percussion, and obeys the general laws governing the transmission of movement. Furthermore, in bodies which suffer impact, there are infinitely tiny oscillating segments, and stationary nodes or points which are immeasurably close together; these oscillating segments and these nodes are the cause of the tremor which we can feel upon touching the body after the impact, sometimes in the absence of any local transmission and sometimes once it has ended. This assumption fits in with the nature of the tremor, which does not run from the whole of the surface which has been touched to the whole of the surface of the sensitive area which touches, but from innumerable points (which are distributed over the surface of the body which has been touched) vibrating confusedly between infinite numbers of stationary points; apparently the force of inertia in continuous elastic bodies, evenly distributed throughout the mass, serves at a given point as a small obstacle in relation to some other point. Furthermore, assuming that the struck section of a vibrating string is infinitely small – and hence has infinitely small bulges, and nodes occurring immeasurably close together, an impression can be gained from this linear (and, so to speak, unidirectional) event of what takes place multi-directionally in one solid body impacted by another. As the length of the intercepted section of the vibrating string is a given, there is nothing which can cause the number of stationary points to be multiplied in the other section; since the number of these points is the same, irrespective of the force of the impact,[60] and since it is only the speed of the oscillations which varies, then, in the impact between the bodies, the tremor will have greater or lesser force; yet the relationship between the number of vibrating and stationary points will be the same, and the amount of matter in repose in these bodies will remain constant, whatever the force of the impact, the density of the body and the cohesion between the parts.[61] All the geometrician would then have to do would be to extend the calculations for the vibrating string to prisms, spheres and cylinders in order to establish the universal law

of the distribution of motion in an impacted body - a law which, until now, we had not even begun to look for, since the existence of this phenomenon had not even been conceived, and we had supposed quite the reverse: motion had been assumed to be evenly distributed throughout a mass, even though, upon impact, the tremor indicated to the senses the presence of vibrating points distributed amongst stationary ones. I use the words 'upon impact,' since it is likely that in the transmission of motion in which impact plays no part, a body is projected in the same way as the smallest molecule would be, and that movement is uniform throughout the entire mass simultaneously. The tremor is non-existent in such cases, and this serves to distinguish instances of impact from those in which it does not occur.

2. All the forces acting on a given body can always be reduced to only one by using the principle of the resolution of forces; if the degree and direction of the force acting on the body are given, and an attempt is made to determine the resulting movement, it will be found that the body proceeds as if the force were passing through the centre of gravity and that, in addition, it rotates around the centre of gravity, as if the centre were fixed and the force were acting around the centre as around a fulcrum. Hence, if two molecules are attracted to each other, they will arrange themselves in relation to each other according to the laws governing their attraction, configuration, etc. If this system consisting of two molecules attracts a third, and is in turn attracted by this third molecule, these three will arrange themselves in relation to one another according to the laws governing their attraction, configuration, etc., and the same will be true of other systems and other molecules. They will form an entire system (A) in which, irrespective of whether or not they touch and whether or not they move, they will be resisting a force which would tend to disrupt the co-ordination between them; they will continually tend either to return to their initial order (if the disruptive force should happen to desist), or else to co-ordinate their actions in relation both to the laws governing their attraction, configuration, etc. and to the action of the disruptive force (if it persists). This system (A) is what I shall refer to as an 'elastic' body.[62] In this general, abstract sense, the solar system and the universe constitute an 'elastic' body: chaos cannot exist, for there is an order which necessarily ensues from the primary properties of matter.[63]

3. If we consider system (A) in a vacuum, it will be indestructible, immutable and eternal; if we suppose its constituent parts to be

disseminated in the vast expanse of space, just as properties such as attraction extend *ad infinitum* once there is nothing to restrain their field of action,[64] then these parts, whose configurations will not have varied at all, and which will be subject to the action of the same forces, will again co-ordinate as before, and will once more form, at some point in time and space, an elastic body.

4. This would not be the case if we were to take system (A) as existing in the universe; the ensuing effects would be no less necessary, although sometimes a fully-determined causal action could not possibly be at work; the causes which combine are always so numerous in the overall system or the universal elastic body, that we know neither what individual systems or elastic bodies may have been like originally, nor what they will become. Thus, without claiming that, in a plenum, attraction constitutes solidity and elasticity as we know them, is it not obvious that, in a vacuum, this property of matter is sufficient on its own to constitute these qualities, and to give rise to rarefaction, condensation and all the other phenomena which depend on them? Why, then, could it not be the primary cause of these phenomena in our overall system, in which an infinite number of causes working to modify this same property could bring about infinite variations in the numbers of these phenomena within particular systems or elastic bodies? Hence, an elastic body, when stretched, will break only when the cause drawing its parts together in one direction has drawn them so far in the other that they will no longer exert any noticeable attraction on one another; an elastic body will only burst upon impact when several of its vibrating molecules have been drawn, during their initial oscillation, such a distance from the stationary molecules amongst which they are distributed that they no longer exert any noticeable mutual attraction upon one another. Should the force of the impact be so great that the vibrating molecules were all drawn beyond their effective sphere of attraction, the body would be reduced to its elements. But, between such an impact – the strongest a body can experience – and one which would only produce the faintest tremor, there exists a degree of impact (which may be real or simply one which we can imagine), following which all constituent elements of the body, having separated, would no longer touch one another without their system being destroyed and their co-ordination ceasing. We shall leave to the reader the task of applying these same principles to condensation, rarefaction, etc. It only remains for us to reiterate the difference between the transmission of motion through

impact, and in the absence of impact. All the parts of a body, in the absence of impact, are transported equally and simultaneously; whatever the degree of motion imparted by this means, even if it were infinite, the body will not be destroyed, but will remain intact until some impact causes some of its components to oscillate amongst others which remain stationary; the peak of the first oscillations then reaches an amplitude at which the oscillating parts can no longer either return to their starting-point or become systematically co-ordinated once more.[65]

5. All the foregoing observations apply, strictly speaking, only to simple elastic bodies or systems of particles of the same matter and with the same configuration, activated by the same degree of force and driven by the same law of attraction. But if all these properties are variable, this will give rise to an infinite number of heterogeneous elastic bodies. By this I mean a system made up of two or more systems of different types of matter, with different configurations, activated to varying degrees, and perhaps even moving in accordance with, different laws of attraction, with particles co-ordinated among themselves by a law governing them all, which may be regarded as the product of their interaction.[66] If this composite system could be simplified by a few scientific operations to expel all the particles from one type of co-ordinated matter, or if it could be further compounded by introducing a new type of matter with particles interacting with those of the system, and hence changing the law governing all of them; then, the solidity, elasticity, compressibility, potential for rarefaction and other factors dependent – in the composite system – on the differing degrees of co-ordination between particles, will then increase or diminish, and so on. Accordingly, lead, which is not particularly solid or elastic, declines further in solidity and increases in elasticity when smelted, a process which consists of making a system composed of lead molecules interact with another consisting of air molecules, fire molecules, etc. which together make it into molten lead.[67]

6. These ideas could very easily be applied to innumerable other similar phenomena, and a lengthy treatise could be written on them. The hardest discovery to make would be to identify the mechanism whereby parts of a system, when they co-ordinate with the parts of another system, sometimes simplify the latter, driving out from it a system of other co-ordinated parts, as happens in certain chemical procedures. Attraction governed by different laws does not appear to offer an adequate explanation of this phenomenon, and it is hard to

admit the possibility of repulsive properties. This difficulty could be avoided as follows: Let us postulate a system (A) made up of systems (B) and (C), the molecules of which co-ordinate with one another according to some law applying to all of them. If we introduce a fourth system (D) into composite system (A), one of two things will happen: either the particles belonging to system (D) will co-ordinate with the constituent parts of system (A) without involving any impact, in which case system A would be made up of systems B, C and D; or, alternatively, co-ordination between particles belonging to system (D) and those of system (A) will be accompanied by an impact. If the impact is such that the particles which suffer it are not carried by their initial oscillation beyond the infinitely small sphere of their attraction, then disruption or innumerable slight oscillations will occur initially. But this disruption will soon end; the particles will co-ordinate, and from their co-ordination will result a system (A) made up of systems (B), (C) and (D). Should the constituent parts of system (B), those of system (C), or of both, be impacted at the very onset of co-ordination, and carried beyond their sphere of attraction by components of system (D), they will then be separated from the process of systematic co-ordination, and will not return to it again; system (A) will thus be a system composed either of systems (B) and (D) or of systems (C) and (D), or else it will be a simplified system consisting solely of the co-ordinated particles of system (D). These phenomena will occur in circumstances which may either greatly enhance – *or totally demolish* – the probability of these ideas. It should be added that I have reached this stage by taking as my starting-point *the vibration of an elastic body under impact.* Separation will never be spontaneous in the presence of *co-ordination*, although it could take place spontaneously where there is *composition* only. *Co-ordination* is also a principle associated with *uniformity*, even in a heterogeneous *whole.*[68]

XXXVII. *Conjectures: sixth series*

What the arts produce will remain commonplace, imperfect and feeble so long as no attempt is made to imitate nature more rigorously. Nature is slow and stubborn in its workings. It always advances towards its goals by the most imperceptible stages, whether distancing, approaching, combining, dividing, softening, condensing, hardening, liquefying, dissolving or assimilating. Art, on the other hand, makes haste, tires and slackens. Nature takes centuries to form metals crudely, while art sets out to perfect them in a single day. Nature takes

centuries to shape precious stones, whereas art aims to counterfeit them in an instant. Even if we had the right means at our disposal, it would not be enough; we would still need to know how to apply them. It would be a mistake to imagine that, as the product of the intensity of the action multiplied by the time it occupies is the same, the result will also be the same. Transformation can be achieved only through slow, gradual and continuous application. Any other kind of application is merely destructive. How much we would gain by combining certain substances which yield only very imperfect compounds, if we were to proceed in a similar way to nature! But we are always impatient to have the satisfaction of completing anything we have begun. This explains all our fruitless endeavours, all our wasted expenditure and effort; so many works are suggested by nature which art will never attempt to emulate, because the chances of success seem so remote. Who was it who came out of the caves at Arcy unconvinced, from the speed at which stalactites are formed and grow again when they are damaged, that these caves will one day fill up and consist of nothing but a huge solid mass?[69] What naturalist, having pondered this phenomenon, has not postulated that by causing water to filter gradually through the ground and rock, and to drip into great empty caverns, it might eventually be possible to form quarries of artificial alabaster, marble and other types of precious stones, with properties which would vary depending on the nature of the ground, the water and the rock? But what is the use of these views without the stamina, patience, toil, expenditure, time and, above all, that taste which the Ancients had for great projects, to which so many memorials still exist, but to which we react with only cold and sterile admiration?

XXXVIII. *Conjectures: seventh series*

So many unsuccessful attempts have been made to convert our iron into steel equal to that of England and Germany, so that it could be used in the manufacture of delicately-crafted products.[70] I do not know what processes have been followed; it seems to me, however, that we would have been led to make a major discovery by emulating and perfecting an operation widely used by workers in iron-foundries. It is known as *puddling*. Puddling consists of taking the hardest soot, grinding it down, diluting it with urine, adding crushed garlic, old shoe leather which has been shredded, and common salt. Taking up a metal container, cover the base with a layer of this mixture, and place on it another layer of various pieces of ironwork, followed by a layer of

the mixture, and so on, until the container is full. Replace its cover and coat the outside neatly with a mixture of heavy, compressed earth, wadding and horse dung. Place the container at the centre of a heap of charcoal proportionate to its volume; light the charcoal, leave the fire to burn, and just make sure that it does not go out. Take a container filled with cool water and, three or four hours after setting the container on the fire, remove and open it, dropping the pieces inside it into the cool water, stirring as the pieces are dropped in. These pieces are tempered by puddling and if some of them are broken apart, it will be found that the surface is covered with a very hard, fine-grained layer of steel to a shallow depth. This surface takes on a brighter polish, and will retain more effectively the shape it is filed into. Is there not a good chance that, once it has been exposed, layer upon layer, to the action of the fire and of the materials used in puddling, carefully-selected iron, which has been properly worked and made as thin as sheet-metal, or into very fine rods, and thrust, the moment it leaves the steel-making furnace, into a stream of water suitable for this process, would then be converted into steel? Especially if the task of conducting these initial experiments were entrusted to men who, long accustomed to dealing with iron, able to recognise its properties and to remedy its defects, would be sure to simplify the procedures and find materials more suitable for the process.

XXXIX. Will the presentation of experimental science in public lectures be enough to inspire the sort of philosophical frenzy I have described? I very much doubt it. Lecturers who perform experiments rather put one in mind of the man who imagines that he has given people a large meal because he has a crowd at his table. The main aim (pursuing the analogy) should be to whet the appetite so that some people, carried away by the urge to satisfy it, progress from being followers to being enthusiasts, and ultimately to taking up the profession of philosopher.[71] Every public figure should distance himself from such reservations, which are utterly inimical to scientific progress. Things in themselves should be revealed, as well as the means of achieving them.[72] The first men who discovered modern calculus through their power of invention were, in my view, very great men indeed! And how petty they seem to me in the mystery they created around it! Had Newton hastened to speak out, as the interests of his own glory and of the truth demanded, Leibnitz would not now share with him the title of joint inventor.[73] The German thought of

the instrument, whereas the Englishman delighted in amazing scholars with astonishing ways of applying it. In mathematics and in the natural sciences, the most reliable way to start is to establish one's proprietorial rights by presenting one's credentials to the public. I should add that when I urge that the methods used should be revealed, I refer to those which have led to success; those which have not should be dealt with as succinctly as possible.

XL. It is not enough to reveal something; any revelation should be clear and complete. There is a type of obfuscation which could be defined as *the affectation of the great masters*. It serves as a veil which they enjoy drawing between nature and the public. Setting aside the respect due to famous names, I take the view that this kind of obscurity prevails in some of Stahl's* works and in Newton's *Principles of Mathematics*.[74] These books needed only to be understood to be valued as they should be, and their authors would have needed only a month to make them clear – a month which would have spared a thousand good minds three years of labour and fatigue. This comes to about three thousand wasted years in all, which could have been spent on other things. Let us hasten to popularise philosophy. If we want philosophers to lead the way, let us see that the public comes close to the point which the philosophers have reached. Will they say that there are works which can never be made accessible to ordinary minds? If they do, they will only be showing that they do not know what the right approach and force of habit can achieve.

If certain writers were entitled to be obscure (and at the risk of being accused of composing my own apologia here),[75] I venture to say that this would apply only to metaphysicians. Great abstractions glow with only a pale light. The very act of generalising tends to strip concepts of anything tangible, and as it progresses, so physical spectra fade away; concepts gradually move away from the realm of imagination towards that of the understanding, and ideas become purely intellectual. The speculative thinker then comes to resemble a man who watches from those mountain tops whose summits are lost in the clouds: the objects visible on the plain have disappeared before his eyes, so that all that remains with him is the spectacle of his own thoughts, and an awareness of the heights he has reached, where others may be unable to follow him and breathe the same air.

* The *Specimen Becherianum*; the *Zimotechnie*; the *Trecenta*; See the article 'Chimie' in vol. IV of the *Encyclopédie* (*Note by Diderot*).

XLI. Is nature not veiled enough already, without shrouding it in yet more mystery? Is our art not already beset with enough difficulties? Open a book by Franklin;[76] thumb through those written by chemists, and you will see how heavily the art of experimentation depends on opinions, imagination, sagacity and resources: read them through attentively because, if it is possible to discover in how many different directions an experiment can go, this is the place to find out. If, for lack of inspiration, you require some technical device to guide you, keep in front of you a table of the properties already observed in matter;[77] see which of these properties may be suited to the substance on which you intend to perform trials; make sure that they are there, and then attempt to measure them; this almost always requires an instrument, to which a constituent analogous to the substance can be applied uniformly and continuously, until nothing is left over and the property is completely exhausted.[78] The question of whether a property exists will only be resolved by means which are not immediately obvious. Even if we do not learn how to conduct the search, it is at least something to know what we are looking for. What is more, those who are forced to acknowledge inwardly their own barrenness, either because of their well-attested inability to make any discoveries themselves, or because they secretly envy the discoveries made by others, or because of the chagrin they feel despite themselves, and the petty manoeuvrings they willingly indulge in to share in the honour of a discovery, would do well to give up a science they practice without enhancing it – or adding to their own reputation.

XLII. Once one of those systems requiring experimental verification has taken shape in the mind, it is a mistake to adhere to it too stubbornly or to abandon it too readily.[79] We sometimes regard our conjectures as false without having taken the appropriate steps to establish that they are true. Here, stubbornness is actually less of a disadvantage than the opposite extreme.[80] By means of repeated trials, even if we fail to find what we are looking for, we may happen to find something better. Time spent consulting nature is never completely wasted. Its consistency should be measured by force of analogy.[81] Completely outlandish ideas do not warrant more than one trial. Those which look more plausible should be pursued, and those which appear to be leading to a significant discovery should not be abandoned until one feels defeated. I do not think there is any need to labour the point. Our dedication to research is naturally proportionate to the interest we take in it.

XLIII. As the systems under discussion are propped up by nothing more than vague ideas, mild suspicions, deceptive analogies - and yes, to be frank – by illusions which the excited mind readily takes to be valid viewpoints, no system should be dropped without first being put to the 'inversion' test.[82] In exclusively rationalist philosophy, truth is quite often taken as the complete opposite of error; similarly, in the experimental school, the phenomenon which was expected may be produced not by the experiment which has been carried out, but by its contrary. It is important to given special consideration to the two diametrically opposed points. This is why (to return to the second series of these reveries),[83] having covered the equator of the electrical globe and left the two poles uncovered, the poles should then be covered and the equator left uncovered; and, since it is important to make the simulation resemble the real globe as closely as possible, the choice of material used to cover the poles will also have some bearing on the question. It might be necessary to introduce accumulations of a fluid, as it is perfectly possible to do in practice, making the experiment yield some remarkable new finding which may differ from what was originally envisaged.

XLIV. Experiments must be repeated to establish the relevant conditions in detail, as well as to determine limits. They should be applied to different objects, and made more complex, in all their permutations and combinations. Whenever experiments have been sketchy, isolated, unconnected and incapable of being reduced to a simple result, this last characteristic itself shows that there is still a good deal to be done. We must then take hold of our subject and worry at it, so to speak, until the phenomena have been so firmly linked together that, if one is given, all the rest will follow. Let us first set about reducing effects to a simpler form; the reduction of causes will come afterwards. Effects can never be reduced to simple terms except by increasing their numbers. In employing the means to extract as much as possible from a given cause, the great art is to distinguish properly between those which might be expected to yield a new phenomenon and those which are capable only of producing a known phenomenon in a different disguise. Dwelling endlessly on such metamorphoses leads to exhaustion and stifles progress. Any experiment which does not extend the application of a law to some new case, or which does not use some exception to qualify it, is meaningless. The shortest way of discovering the value of a trial one is

making is to take it as the first premise of an enthymeme[84], and then examine what follows. Is the consequence exactly the same as the findings from another trial? If so, no discovery will have been made; at most, a discovery will have been confirmed. There are few weighty tomes on experimental science which cannot be reduced to a few pages by this extremely simple rule; and plenty of smaller works might be reduced to nothing at all.

XLV. Just as, in mathematics, we find, on examining all the properties of a curve, that the same property is present throughout in different guises, so it will also be recognised, when experimental science is more advanced than at present, that all phenomena, whether we refer to weight, elasticity, attraction, magnetism or electricity, are no more than different aspects of the same property.[85] But, amongst the known phenomena which are attributed to one of these causes, how many intermediate phenomena are still waiting to be discovered before connections can be created, voids can be filled, and identity can be demonstrated? This we cannot determine. There could be some central phenomenon at work which sheds its light not just on those phenomena which are already known, but also on all those which will emerge in time, uniting them and arranging them into a system. But in the absence of this unifying focal point, they will remain in isolation; all the discoveries of experimental science will serve only to draw them closer together, without ever uniting them; and, should such discoveries ever succeed in uniting them, the result would be a continuous circle of phenomena, in which the first could not be distinguished from the last. This singular occurrence, whereby experimental science, by sheer effort, would have produced a maze in which rationalist science could only wander round and round, helpless and lost, is not impossible in the natural sciences as it is in mathematics. In mathematics, intermediate propositions can always be found, by synthesis or analysis, which separate the fundamental property of a curve from the most remote of its properties.[86]

XLVI. There are deceptive phenomena which, at first sight, appear to overturn a system but which, if they were better known, would finally substantiate it.[87] Such phenomena become a torment for the philosopher, especially when he has the feeling that nature is inflicting it on him, and shielding itself from his speculations by some strange and secret mechanism. This uncomfortable situation occurs

whenever a given phenomenon arises from several conjoined or conflicting forces. When they are conjoined, the scale of the phenomenon will be too great to fit the hypothesis which has been formed; if they conflict, the scale will be too small. It may even shrink to nothing and the phenomenon will disappear, without our having any idea how to explain this sudden, unpredictable silence of nature. Do we begin to suspect the reason why this happens? That really doesn't get us much further. An effort must be made to separate the causes, to analyse the results of their actions, and to reduce a very complicated phenomenon to a simple one; or at least to reveal, by some new experiment, the complex nature of these causes, and the ways in which they complement or oppose one another; this is often a delicate, and sometimes impossible, operation. Then the system totters; philosophers are divided in their opinions; some still adhere to the system, while others are swept along by the experiment which appears to refute it. The disagreement continues until either wit or chance (which is never idle - and is more fruitful than man's wit) removes the contradiction and reinstates ideas which had been all but abandoned.[88]

XLVII. Experimentation must be given a free rein; to show only what confirms our findings and conceal what conflicts with them would be to hold it captive. Therein lies the drawback, not in having ideas as such, but in letting oneself be blinded by them when carrying out an experiment.[89] We use our critical judgement only when the result conflicts with the system. Nothing is then omitted which could alter the aspect of the phenomenon, or the language of nature. If the opposite occurs, the observer is indulgent; he glosses over the circumstances, and hardly bothers to raise objections in the face of nature; he takes her at her word; he suspects no ambiguity, and he deserves to be told 'Your task is to ask questions of nature, but you are either making her lie, or else you are afraid to make her explain herself.'

XLVIII. When we have taken the wrong road, the faster we walk, the more we goes astray. But how can anyone retrace his steps once he has covered a huge distance? Sheer exhaustion does not allow him to do so; and vanity, too, bars our way without our realising it; a stubborn attachment to principles gives everything surrounding us an illusory appearance which distorts objects. Things are then no longer seen as they are, but as they ought to be. Instead of modelling our ideas on real beings, it seems that we make every effort to construe

beings on the basis of our ideas. Of all the different schools of thought, none is so clearly overcome by this craze as the 'methodists'.[90] As soon as one of their number has devised a system which places man at the head of the quadrupeds, he sees him in nature as nothing more than a four-footed animal. The incomparable reasoning faculty with which man has been gifted cries out against the term 'animal', and his organism belies the description of 'quadruped', but in vain; nature may well make man look heavenwards - his systematising bias will still bend his body towards the ground. This same bias leads people to maintain that reason is merely a more perfect form of instinct, and to believe, in all seriousness, that it is only because he has grown out of the habit that man loses the use of his legs when he decides to transform his hands into two feet.[91]

XLIX. Indeed, the arguments used by some of the classifiers are so strange that an example needs to be given here. Man, says Linnæus in the preface to his *Fauna Suecica*,[92] is neither a stone nor a plant; he must therefore be an animal. He does not have only one foot, so he cannot be a worm. He is not an insect because he has no antennae, nor a fish, because he has no fins, nor a bird, because he has no feathers. So what is man? He has a mouth like a quadruped. He has four feet; he uses the two fore-feet to touch with, and the two hind-feet to walk with. So he must be a quadruped. The Linnæan goes on to say: 'It is true that, as a consequence of my theories about natural history, I have never been able to distinguish between man and ape, because there are certain apes which have less hair than certain men: these apes walk on two legs and use their hands and feet like men. Nor do I consider speech to be a distinguishing feature; my method only allows for those features which are dependent on number, contour, proportion and situation.' 'So your logic must be wrong', the logician will say; and the naturalist will conclude that man is a four-footed animal.[93]

L. To shatter a hypothesis, it sometimes needs only to be taken to its logical conclusion. We shall now put this approach to the test in the case of the doctor of Erlangen,[94] whose book, teeming as it is with extraordinary new ideas, will put any philosopher on the rack. His subject is the greatest that human intelligence can address: nature as a universal system. The author begins with a rapid exposé of the views of his predecessors, and the reasons why their principles are

inadequate to explain the overall development of phenomena. Some philosophers require only *extension* and *motion*.[95] Others have found it necessary to enlarge upon extension by adding *impenetrability*, *motility* and *inertia*.[96] Observation of the heavenly bodies, or the scientific study of large bodies in general, has pointed to the need to postulate a force or law according to which all the parts are drawn towards, or weigh upon, one another; and the force of *attraction*, in direct ratio to mass and in inverse proportion to the square of the distance, is now generally accepted.[97] The simplest chemical procedures, or the elementary physics of small bodies, have entailed a resort to forms of *attraction* which follow other laws; the impossibility of explaining the formation of a plant or animal by means of attraction, inertia, motility, impenetrability, motion, matter or extension has led the philosopher Baumann to attribute yet further properties to nature. Dissatisfied with the idea of a *plastic nature*, which can be made to perform all the wonders of nature without resorting to matter or intelligence;[98] rejecting *subordinate intelligent substances*, which exert some unintelligible action on matter; refusing to accept the *simultaneity of creation and the formation of substances* which, being contained within one another, develop over time as a continuation of the first miracle;[99] and, lastly, rebutting the idea that *they are produced extemporaneously*, which makes them nothing more than a chain of miracles repeated with each moment that passes, he has come to the view that all these rather unphilosophical systems would never have arisen were it not for a groundless fear of attributing well-known modifications to a being whose essence is unknown to us - and who is, for this very reason, despite our preconceptions, entirely compatible with such modifications. But what is this being? and what are these modifications? Dr Baumann asks: 'Shall I tell you?', and he answers: 'This being is a physical one; these modifications are *desire, aversion, memory* and *intelligence*' – in a word, all the qualities which we recognise in animals, which the Ancients referred to as a *sensitive soul*, and which Dr Baumann recognises, keeping form and mass in proportion, in anything from the smallest particle of matter to the largest of animals.[100] If, he says, there were any danger in attributing some degree of intelligence to molecules of matter, that danger would be equally great, whether we were dealing with an elephant or an ape, or even imagining it in a grain of sand. It is here that the philosopher of the Erlangen Academy uses every effort to deflect any suspicion of atheism on his part; and it is obvious that he hotly defends his

hypothesis only because it appears to him to deal with the most challenging of phenomena, without leading inevitably to materialism.[101] Anyone who wishes to learn how to reconcile the boldest philosophical ideas with the deepest respect for religion should read his book. God created the world, says Dr Baumann, and it is up to us to find, if possible, the laws according to which He wished it to remain in being, and the means He has prescribed for the reproduction of the species. We are perfectly at liberty to put forward our ideas in this regard; and the doctor's main ideas are as follows:[102]

The seminal element issues from a part resembling the part which that element is later to form in the animal; it is sentient and thinking, and will retain some memory of its origins – this explains the preservation of species and the resemblance which offspring have to their forbears.

It may happen that seminal fluid has either an excess or a lack of certain elements and that, as a result of a lapse of memory, these elements cannot unite; it may also happen that strange combinations of superfluous elements are formed, resulting either in an inability to reproduce, or in the creation of every possible type of monstrosity.

Certain elements will inevitably have acquired a prodigious facility for always combining in the same way; it follows that infinitely varied microscopic creatures will be formed if the elements differ, and polyps if they are alike; the latter may be compared to a cluster of infinitely small bees which can store only one position in their memory, clinging to one another and remaining there in accordance with that position, which is the one most familiar to them.[103]

When the impression of the present situation counterbalances or extinguishes the memory of some past situation, resulting in indifference to all situations, sterility will ensue; that is why mules are sterile.

What is there to prevent primary intelligent and sentient components from diverging immeasurably from the pattern which determines a species? This would give an infinite number of animal species derived from one original animal; an infinite number of beings deriving from one original being: in short, a single act of nature.[104]

But, in the process of accumulation and combination, could each element lose its small store of feeling and perception?[105] Not at all, according to Dr Baumann. These qualities are vital to it. So what will happen? This: from these perceptions of assembled and combined elements, a single perception will arise, which is proportionate to the mass and to the configuration of what is perceived; and the system of

perceptions in which each element has lost its recollection of the *self*, and will play its part in forming the consciousness of *the whole*, will be the creature's soul. *Omnes elementorum perceptiones conspirare, et in unam fortiorem et magis perfectam perceptionem coalescere videntur. Haec forte ad unamquamque ex aliis perceptionibus se habet in eadem ratione qua corpus organisatum ad elementum. Elementum quodvis, post suam cum aliis copulationem, cum suam perceptionem illarum perceptionibus confudit, et sui conscientiam perdidit, primi elementorum status memoria nulla superest, et nostra nobis origo omnino abdita manet.**[106]

At this point, we are surprised that the author did not realise the dreadful consequences of his hypothesis; or, if in fact he did realise the consequences, that he did not abandon it.[107] The time has come to apply our method to testing his premises. Accordingly, I shall ask him whether the universe or the entire array of all sentient and thinking molecules forms a whole or not. Should he reply that it does not form a whole, then, with a single word, he will undermine the existence of God, by introducing disorder into nature, and he will destroy the very basis of philosophy by breaking the chain which links all beings together.[108] If he agrees that it does indeed form a whole, in which the elements themselves are no less well ordered than are their constituent parts (whether those parts actually differ from one another, or are merely thought of as doing so), and no less well ordered than these elements, in turn, are in any living creature, then he would have to allow that, as a result of this universal connection between things, the world has a soul, as though it were some great animal; and that, since the world may be infinite, this world-soul may be - although I do not say that it is - an infinite set of perceptions, and that the world could be God.[109] He can protest as much as he wishes against such consequences – they are nonetheless true; and whatever light his sublime ideas may cast upon nature's hidden depths, these ideas still remain just as terrifying. All it needed for this to become apparent was to apply them generally. Generalisation is, for a metaphysician's hypotheses, what repeated observation and experimentation are to the conjectures of the empirical scientist. Are these conjectures borne out? The more experiments are performed, the more these conjectures are verified. Are the hypotheses valid? The wider the consequences

* See paragraph 52, page 78 [of the *Dissertatio*]for this section; and in the pages which precede and follow it will be found some very astute and very convincing examples of how these principles can be applied to other phenomena (*Note by Diderot*).

range, the more truths they embrace, and the more compelling the evidence they provide. If, on the other hand, the conjectures and hypotheses are only weak and ill-founded, either some fact will be discovered, or some truth will emerge on which they founder. Dr Baumann's hypothesis may well unlock the most unfathomable mystery of nature – how animals or, more generally, organisms of any kind are formed – but he faces two pitfalls: the entire array of phenomena in the universe, and the existence of God. While rejecting the ideas put forward by the doctor of Erlangen, we would still have found difficulty in coping with the obscure phenomena which he set out to explain, the richness of his hypothesis, the surprising consequences which can be drawn from it, the value of his new speculations on a subject which has preoccupied the most outstanding figures throughout the centuries, and the difficulty of successfully challenging such speculations - had we not seen these things as the fruits of profound meditation, and a bold attempt by a great philosopher to tackle the entire system of nature.[110]

LI. ***On the impetus of sensation***

If Dr Baumann had confined his system within reasonable limits, and had applied his ideas only to the formation of animals, without extending them to encompass the nature of soul (from which I believe I have shown, whatever he may say, that they could even be applied to the existence of God), he would never have rushed into the most seductive form of materialism by attributing desire, aversion, feeling and thought to organic molecules.[111] He should have been content to suppose that they were capable only of feelings a thousand times less intense than those which the Almighty has bestowed upon the stupidest creatures who are closest to lifeless matter. As a result of this subdued sensitivity and the difference in configuration, there would never have been more than one position to suit any given organic molecule, and that position would have been the most comfortable of all; this is the position which it would constantly have sought, with an unthinking restlessness, just as when animals stir in their sleep, and the use of almost all their faculties is suspended, until they find the position most conducive to their rest. This one principle would have accounted satisfactorily, simply, and without any dangerous consequences, for the phenomena which he set out to explain, and the innumerable wonders which so dazzle our entomologists. He would then have defined living creatures in general as a *system of different*

organic molecules which, under the impetus of a sensation similar to a dull, blunt feeling of touch granted to them by the creator of matter in its entirety, have combined with one another until each finds the place best suited to its configuration and its repose.[112]

LII. ***On instruments and measurements***

We have observed elsewhere that as the senses were the source of all our knowledge, it was most important to know how far we could rely on their testimony;[113] at this point it should be added that testing by using an extension of our senses – in other words, instruments – is equally essential. This is a new application of experimentation, and it means another source of long, arduous and difficult observations. There might be one way of cutting down the work: namely, to close one's ears to a kind of scruple attaching to rationalist philosophy (for it does have its scruples), and to have a proper grasp of whether the accurate measurement of quantities is necessary in all cases.[114] Think of all the effort, work and time wasted on measurement which could have been better spent on discovery!

LIII. In both the invention and the perfecting of instruments, there are precautions which cannot be too strongly recommended to the empirical scientist, i.e. to mistrust analogies;[115] never to extrapolate from major to minor instances, nor from minor to major ones,[116] and to scrutinise all the physical properties of the substances used. The empirical scientist will never succeed if he omits to do these things and, even when he has taken all the precautions he can, how often will it still happen that some minor obstacle, which he has either failed to foresee or which he has dismissed with contempt, will set a natural limit to his work, and force him to abandon it when he believed it to be complete?

LIV. ***On distinguishing objects***

The mind cannot comprehend, nor the imagination predict, everything; the senses cannot observe, nor the memory retain, everything; great men are born at such rare intervals, and scientific progress is interrupted to so great an extent by revolutions, that centuries of study are required to recover the knowledge of past centuries; for these reasons, it would be failing the human race to provide imprecise observations of everything. Men of outstanding talent must respect both themselves and posterity in the way they use their time. What

would posterity think of us, if all we had to leave behind was a complete entomology or a vast survey of microscopic creatures?[117] Let great minds tackle great subjects, and lesser minds concern themselves with lesser ones; they are better occupied with such matters than doing nothing at all.

LV. ***On obstacles***

And since it is not enough to desire something, and since we have to accept at the same time everything which is almost inseparably linked to what is desired, anyone who has decided to apply himself to the study of philosophy should expect to encounter not just the physical obstacles associated with his subject, but also the numerous moral obstacles which will certainly beset him, as they have beset every philosopher before him. So, once he has been flouted, misunderstood, slandered, compromised and torn apart, he should be able to say to himself: 'Is it only in my century - and only in my case - that there have been people filled with ignorance and venom, spirits devoured by envy, and minds clouded by superstition?' If he sometimes believes that he has grounds to complain about his fellow-men, let him tell himself this: 'I do complain of my fellow-men, but, if it were possible to question all of them, and ask each one whether he would prefer to have been the writer of the *Nouvelles Ecclésiastiques* or Montesquieu, and the author of the *Lettres Américaines* or Buffon,[118] is there a single one who, if he had a little discernment, might have hesitated in his choice? I am therefore sure to receive some day the only plaudits I value, if I have had the good fortune to deserve them.'

And you, who take for yourselves the title of philosophers or intellectuals, and are not ashamed of resembling those troublesome insects which spend every moment of their fleeting existence disturbing man during his work and rest – what is your purpose? What do you expect from your furious efforts? Once you have disheartened the authors of any renown, and the outstanding geniuses which the nation still has, what will you then do in your turn for the national good?[119] What wondrous productions will you provide to compensate the human race for those it would have received? ... Despite what you do, the names of Duclos, d'Alembert and Rousseau, those of Voltaire, Maupertuis and Montesquieu, and those of Buffon and Daubenton, will still be honoured by us, and by our descendants; and if someone, some day, remembers your own names, he will say,

'They were the persecutors of the greatest men of their times; and if we now have the preface to the *Encyclopédie*, the *Histoire du Siècle de Louis XIV*, the *Esprit des Lois* and the *Histoire de la Nature*, it is because, fortunately, those people were powerless to deprive us of them.'[120]

LVI. ***On Causes.***

1. Were we to consult only the vain conjectures of philosophy and the faint light of our reason, we should believe that the chain of causes had no beginning, and that the chain of effects will have no end.[121] Imagine that a molecule has moved: it has not moved of its own accord; the cause of its movement has another cause; this in turn has its cause – and so on, without our ever reaching the *natural* limits of causes in the past. Now imagine that a molecule moves; its movement will have its effect, and this effect in turn will have another effect, and so on, without our ever reaching the *natural* limits to effects in the future. The mind, terrified by this infinite progression towards the most trivial causes and the slightest effects, rejects this supposition - and certain others of the same type – only because it has a preconception that nothing takes place takes beyond the realms of the senses, and that everything beyond our view ceases to exist.[122] But one of the main differences between the *observer* and the *interpreter* of nature is that the latter begins at the point where the former ceases to use his senses and his instruments; on the basis of what now exists, he speculates on what is to come; from the established order of things, he draws abstract and generalised conclusions which, for him, have all the force of particular, ascertainable truths; he ascends to the very essence of the natural order, and sees that *the mere fact* that a thinking and sentient being co-exists alongside some kind of connection between causes and effects, is not in itself enough to enable him to make any definitive judgement on them; he stops at that point, and any further step he might take would put him beyond the boundaries of nature.[123]

2. ***On final causes.*** Who are we to explain nature's purposes? Do we not notice that, in commending her wisdom, we nearly always detract from her power, and that we are taking away more from her resources than we could ever attribute to her views?[124] This way of interpreting nature is wrong, even in natural theology,[125] as it substitutes human speculation for the workings of God, and binds the most important of truths to the fortunes of a hypothesis.[126] But the

most commonplace phenomenon will suffice to show how far the search for final causes is the opposite of true science. Supposing that an empirical scientist, when questioned as to the nature of milk, were to reply that it is a foodstuff which begins to form in the female after conception, and which nature intends for the nourishment of the future offspring – what would this definition teach me about how milk is formed? What am I to believe about the supposed purpose of this fluid, and the other physiological ideas accompanying it, when I know that there have been men who have made milk spurt from their breasts; I also know that anastomosis of the epigastric and mammary arteries* shows that milk is the cause of the swelling of the breasts which sometimes inconveniences young girls when their periods are due, and that nearly every girl could breast-feed if she were to suckle a child; in fact, I have before me a female who is so small in size that no male has been found to suit her; she has never mated and has never borne any young, but her nipples are nonetheless so engorged with milk that the usual means have had to be employed to bring her relief? How ridiculous anatomists appear when, in all seriousness, they attribute to coyness on the part of nature the shadow which she has also cast over other parts of the body where there is nothing indecent to hide! The purpose which other anatomists imagine that it serves does rather less honour to nature's modesty, but hardly any greater honour to their sagacity. The empirical scientist, whose profession is to instruct and not to edify, will therefore stop asking *why*, and concern himself only with the question of *how*. The question of *how* is based on actual beings, and the question of *why* is merely a product of our minds; it is associated with the systems we have invented, and depends on the progress of our knowledge. What a multitude of absurd ideas, false speculations and illusory notions are to be found in the hymns which a few headstrong proponents of final causes have ventured to compose in honour of the Creator! Instead of sharing the ecstatic admiration of the Prophet and calling out in the night, at the sight of the innumerable stars which brighten the heavens, *Coeli enarrant gloriam Dei*,[128] they have abandoned themselves to their superstitious conjectures. Instead of adoring the Almighty in nature's own creatures, they have bowed down before the figments of their imagination. Should anyone be bound by preconceptions and doubt

* This anatomical discovery, one of the finest to be made in our time, is the work of M. Bertin (*Note by Diderot*).[127]

the soundness of my reproach, I invite him to compare Galen's treatise on the function of the parts of the human body with the *Physiologie* of Boërhaave, and to compare the *Physiologie* of Boërhaave in turn with that of Haller.[129] I call upon posterity to compare whatever fleeting, systematic views are contained in the latter work with what physiology will become in future centuries. Man attributes the merits of his petty views to an eternal God; and eternal God, who listens to him from His lofty throne, and who realises his intentions, accepts his idiotic praises and smiles at his vanity.

LVII. *On various preconceptions*

There is nothing, either in the workings of nature, or in the conditions of life, which is not a pitfall for the hasty. As examples, I cite most of the popular axiomatic expressions regarded as 'common sense' by every nation.[130] There is a saying that *there is nothing new under the sun*,[131] and that is true for anyone who does not go beyond mere outward appearances. But what sort of maxim is it for the philosopher, whose daily task consists of grasping the most imperceptible of differences? How would it seem to someone who held that, on a whole tree, no two leaves would be *perceptibly* of the same shade of green?[132] How would it be regarded by someone who, speculating on the large number of causes (including those already known) which need to combine in order to produce a colour of exactly the same shade, claimed – without intending any offence to Leibnitz's view – that it has been shown, through the difference between the points in space at which bodies are placed, combined with the prodigious number of causes involved, that perhaps there never was, and perhaps never will be in the whole of nature, two blades of grass of *exactly* the same shade of green? If beings change in gradual stages by passing through the most imperceptible of nuances, then time, which does not stand still, must eventually create the greatest possible difference between forms which existed in the remote past, those existing today, and those which will exist in the distant future;[133] and so the saying *nil sub sole novum* is no more than a preconception based on the inadequacy of our organs, the imperfections of our instruments, and the brevity of our lives. There is a maxim of moral philosophy which says *tot capita, tot sensus* ('there are as many opinions as there are heads to hold them'), but in fact the opposite is true: nothing is so plentiful as heads, and nothing is so rare as opinions. There is a literary saying that *there is no arguing about taste*;

if this means that nobody should argue with a man that his taste is such and such, it is mere childishness. If it means that there is no such thing as good or bad taste, it is false.[134] A philosopher will subject all these expressions of popular wisdom to a stern examination.

LVIII. Questions[135]

Homogeneity can manifest itself in only one way, whereas there are an infinite number of different ways to express heterogeneity. It seems to me just as impossible for all nature's creatures to have been produced from one perfectly homogeneous type of matter as to represent them as all being of the same colour. I think there are even some indications that the diversity of phenomena could not have resulted from just any type of heterogeneity. Accordingly, I shall refer to the different types of heterogeneous matter needed for the general production of natural phenomena as *elements*, and I shall use the word *nature* to denote the existing overall result, or the successive overall results, of the combination of elements. There must be fundamental differences between elements, otherwise everything could have been produced by homogeneity, because everything could return to that state.[136] There either is, was or will be a natural or an artificial combination whereby one element is, was or will be divided as far as possible. The molecule of an element at this final point of division is indivisible; its indivisibility is absolute, since any further division of this molecule, being outside the laws of nature and beyond the power of our techniques, can only be theoretical.[137] The final point of division possible in nature would appear to differ from that lying within the power of artificial means, as far as fundamentally heterogeneous types of matter are concerned; it follows that there are molecules whose mass is essentially different, but which are absolutely indivisible in themselves. How many types of matter exist which are completely heterogeneous, or consist of one single element? We do not know. What are the essential differences between the types of matter which we regard as absolutely heterogeneous or composed of one single element? We do not know. How far can the division of matter composed of one element be taken, either by using man-made techniques or the workings of nature? We do not know - and so on, and so on. I have linked processes which require human intervention with those which occur naturally because, amongst the infinite number of facts which we do not know, and which we will never know, there is one which still remains hidden from us: namely, the

question of whether an element has ever been, is now, or ever will be, split still further by some human technique than it has been, is now, or ever will be, split by any combination of forces when nature is left to its own devices. And it will be seen, from the first of the following questions, why I have introduced references to the past, present and future into some of my proposals, and why I have introduced the idea of succession into my definition of nature.[138]

1. If there is no link from one phenomenon to another, there can be no philosophy. Even if all phenomena were interlinked, the state of each of them might still not be permanent. But if each living being is in a perpetual state of change, even as a result of the workings of nature, then despite the chain which links phenomena together, there is still no philosophy.[139] All our natural sciences become as transitory as the words we utter. What we take for natural history is merely the far-from-complete history of a single instant. I ask, therefore, whether metals always have been, and always will be, as they now are; whether plants always have been, and always will be, as they now are; whether animals always have been, and always will be, as they now are; and so on. A word to sceptics: having meditated profoundly on certain phenomena, you may understandably question not so much the fact that the world was created, but whether it now is as it used to be, and as it will be in the future.

2. Just as in the animal and vegetable kingdoms, an individual comes into being, so to speak, grows, remains in being, declines and passes on, will it not be the same for entire species? If our faith did not teach us that animals left the Creator's hands just as they now appear and, if it were permitted to entertain the slightest doubt as to their beginning and their end, may not a philosopher, left to his own conjectures, suspect that, from time immemorial, animal life had its own constituent elements, scattered and intermingled with the general body of matter, and that it happened that these constituent elements came together because it was possible for them to do so; that the embryo formed from these elements went through innumerable arrangements and developments, successively acquiring movement, feeling, ideas, thought, reflection, consciousness, feelings, emotions, signs, gestures, sounds, articulate sounds, language, laws, arts and sciences; that millions of years passed between each of these developments, and there may be other developments or kinds of growth still to come of which we know nothing; that a stationary point either has been or will be reached; that the embryo either is, or will be, moving

away from this point through a process of everlasting decay, during which its faculties will leave it in the same way as they arrived; that it will disappear for ever from nature – or rather, that it will continue to exist there, but in a form and with faculties very different from those it displays at this present point in time?[140] Religion saves us from many deviations, and a good deal of work. Had religion not enlightened us on the origin of the world and the universal system of being, what a multitude of different hypotheses we would have been tempted to take as nature's secret! Since these hypotheses are all equally wrong, they would all have seemed almost equally plausible. The question of why anything exists is the most awkward that philosophy can raise – and Revelation alone provides an answer.[141]

3. If we glance at animals and the rough ground they tread, at organic molecules and the fluid in which they move, at microscopic insects and the matter which produces and surrounds them, it is obvious that matter is divided overall into two kinds: dead and living.[142] But how can it be that matter does not form a single unity, which is either wholly dead or wholly living? Is living matter always alive? And is dead matter really – and permanently – dead? Does living matter not die at all? Does dead matter never come to life?

4. Is there any ascertainable difference between dead and living matter other than its arrangement, and the real or apparent spontaneity of its movement?

5. Could so-called living matter not simply be matter which moves by itself? And could so-called dead matter not be one type of matter moved by another?[143]

6. If living matter is matter which moves by itself, how can it cease to move without dying ?

7. If there is matter which lives of its own accord, and matter which dies of its own accord, are these two principles sufficient to explain in general terms the production of all entities and all phenomena?

8. In geometry, a real parameter added to an imaginary one gives an imaginary whole; in nature, if a molecule of living matter is applied to a molecule of dead matter, will the whole then be living or dead?

9. If the combination can be either living or dead, at what point will it become living - and why? At what point - and why - will it be dead?

10. Whether living or dead, it exists in some form. In whatever form it exists, what principle governs it?

11. Are forms produced according to a matrix? What is a matrix? is

it a real, pre-existing entity?[144] or does it merely designate the intelligible limits of a living molecule's energy, joined to dead or living matter, and determined by the relationship between energy in its widest sense, and resistance, also in the widest sense? If it is indeed a real, pre-existing entity, how was it formed?

12. Does the energy of a living molecule vary of its own accord? Or does it vary only according to the quantity, quality and shapes of the living or dead matter with which it unites?[145]

13. Are there any types of living matter identifiably different from other living matter? Or is all living matter basically of one type and suitable for everything? The same question can be asked with regard to dead matter.

14. Does living matter combine with living matter? How would it do so? What is the result? Again the same question can be asked with regard to dead matter.[146]

15. Supposing that all matter were living, or that all matter were dead - would there ever be anything other than dead matter (or living matter) or could living molecules not come back to life after losing their lives, only to lose them again, and so on, ad infinitum?

When I turn my gaze to the works of mankind, and I see towns built everywhere, materials of all kinds being used, languages established, nations policed, harbours constructed, seas crossed and the earth and skies measured; the world seems very old to me. But when I encounter people unsure as to the basic principles of medicine and agriculture, the properties of the commonest substances, the diseases affecting them, the height of trees and the shape of the plough, it seems to me that the earth has been peopled only since yesterday. And, if men were wise, they would finally devote themselves to research affecting their welfare, and would not answer my futile questions until at least a thousand years had passed; or perhaps, always bearing in mind how small a part of time and space they occupy, they would never even deign to reply.

THE END

Note to the reader concerning one point is section XXXVI, paragraph 3.

I mentioned, young man, that *properties such as attraction extend* ad infinitum *once there is nothing to restrain their field of action.* It will be objected 'that I could even have said that *they are propagated uniformly.* It will perhaps be added that it is scarcely possible to understand how a quality may be exercised at a distance, without any intermediary, but that there is not – and there never has been – anything absurd in this, although there would indeed be something absurd in claiming that it operates differently in a vacuum, at varying distances; for if that is so, there is nothing, whether inside or outside a portion of matter, which is capable of causing its action to vary; it may also be added that Descartes and Newton, as well as philosophers both ancient and modern, presumed that a body, powered with the slightest degree of motion in a vacuum, would continue *ad infinitum*, at a uniform rate and in a straight line; that distance in itself is thus neither an obstacle nor a vehicle; that any quality whose action varies in some proportion, whether direct or inverse, to distance, must necessarily lead back to the notion of the plenum, and to the corpuscular theory; and that the positing of a vacuum and of variability in causal action are two contradictory notions.' If anyone mentions these difficulties to you, I advise you to go and seek the answer from some Newtonian, for I confess that I do not know how to resolve them.[147]

Notes

1 This short prefatory address was added to the revised edition of 1754.

2 The basis of the charge of atheism levelled against Spinoza (1632–77) was that, in his *Ethica*[*Ethics*] (1677), he had made God and nature identical, and was therefore a materialist. La Mettrie (1709–51) had published his equally notorious *L'Homme Machine* [*Man a Machine*] in 1748, earning himself widespread condemnation as an even more intransigent materialist than Spinoza. Diderot's concern is to avoid being similarly vilified by the defenders of orthodoxy, who had already found much to decry in the 'philosophical' articles of the *Encyclopédie*. The reference to hypothesis is simply a reminder of its status in a work in which its role is central to the endeavours of the scientist.

3 'From the darkness, we behold those things which are bathed in light'. The quotation is taken from Book IV (not Book VI) of the *De rerum natura* [*On the Nature of Things*] (l.337). The reference is intended partly as a criticism of the obscurantism afflicting science at that time, and partly as a hint of the importance with Lucretian atomism will play in the *Interpretation*.

4 An echo of the preface to Bacon's *Novum Organum*.

5 The first volume of Buffon's *Natural History* had appeared in 1749.

6 Diderot is echoing Bacon who, in the *Advancement*, had written that '*Mathematick* and *Logick*, which should carry themselves as handmaids to *Physick*, boasting their certainty above it, take upon them a command and Dominion.' (Book III, Chap. VI).

7 'Metaphysics' in the sense that mathematics has nothing to do with the real world of *physis*, or nature.

8 'Rational' in the sense of 'expressible by numbers'.

9 James Bradley (1692–1762) was the first to measure accurately the diameter of Venus, and in 1747 had discovered the nutation, or slight oscillation, of the Earth's axis. Pierre-Charles Le Monnier (1715–99) had published his *Observations* on the sun, moon and fixed stars in 1751.

10 A reference to d'Alembert in particular, whose *Mélanges de littérature et de philosophie* (containing, *inter alia*, extracts translated from Tacitus) had been published in 1753.

11 This list contains the names of the most illustrious mathematicians of the day: Daniel Bernoulli (1700–82) and his brother Jean (1710–90). Leonard Euler (1701–83); Pierre-Louis Moreau de Maupertuis (1698–1759); Alexis Clairaut(1713–65); Alexis Fontaine des Bertins (1705?–71); Jean Le Rond d'Alembert(1717–83).

12 The Pillars of Hercules were two promontories (one in Spain, the other in Africa) at the entrance to the Mediterranean; the Ancients believed that they had been created by Hercules tearing the land apart, and that they marked the limits of the world accessible by man.

13 There may be a covert reference here to the very popular courses on physics given by the abbé Nollet (1700–1770) and others. But the last sentence indicates that Diderot is thinking particularly of the vogue created by the great success of Buffon's *Natural History*.

14 The tone of this whole section recalls the remarks of Christian apologists such as Blaise Pascal (1623–62) who had sought to humble man's vanity and pride in his achievements. The emphasis is particularly apt, since Pascal had been one of the great figures of mathematics in the previous century. On the importance of this

moralistic tradition in pre-Revolutionary France, see Anthony McKenna *De Pascal à Voltaire: le rôle des 'Pensées' de Pascal dans l'histoire des ideés entre 1670 et 1734, Studies on Voltaire and the Eighteenth century* 276–277 (Oxford, 1990).

15 On the image of the chain linking all phenomena, see the classic study by Arthur O Lovejoy, *The Great Chain of Being* (Cambridge, Mass., 1936, especially chapter VI).

16 Pierre Fermat (1601–65) is best remembered today for his pioneering work (with Blaise Pascal) on the calculus of probabilities.

17 Sennar, or Shinar, was the site of the tower of Babel (*Genesis*, XI, 1–9).

18 An allusion to the competing systems devised by naturalists such as Buffon and Linnæus, to which reference is made in section XLVIII below.

19 The article 'Expérimental' by d'Alembert, published in 1755 in volume V of the *Encyclopédie,* discusses the subject in very similar terms. This similarity of outlook is striking, in view of the obvious differences between the two men with regard to the value of mathematics.

20 D'Alembert had made similar comments on the philosophy of the Dark Ages in the *Preliminary Discourse* of the *Encyclopédie* (1751).

21 The reference is to Pierre Coste (1668–1747), whose edition of Montaigne's *Essais* (1724) earned him the reputation of thinking that he had written the work himself.

22 In the *Preliminary Discourse* of the *Encyclopédie,* the editors had stigmatised their contemporaries' love of false learning as a cover for ignorance, and blamed it as one of the main causes of the barbarism into which France was, they alleged, being plunged.

23 It is important to understand that Diderot had always accepted this principle, though rarely with as much emphasis as in this note and elsewhere in the *Interpretation.* Even in the *Letter on Blindness,* where the idea of monsters looms large, such aberrations are still part of the workings of the natural processes, and not something beyond rational explanation. This is, indeed, the view taken by other writers such as Buffon and Maupertuis.

24 This passage is indeed borrowed from vol. IV of Buffon's *Natural History.* It contains one of the clearest statements to be found in an eighteenth-century text of ideas which might seem to anticipate the evolutionary theories of Charles Darwin. Although he writes in volume I of the *Natural History* that species are fixed and immutable, Buffon also claims that changes in climate and diet can be responsible for significant variations between individuals of the same species. Crucially, however, he does not go on to say, any more than Diderot himself, that these changes are then perpetuated in succeeding generations. Cf. below, note 144.

25 'Baumann' is the name under which Maupertuis published the *Dissertatio.* Unlike Buffon, Maupertuis believed that changes in successive generations were the result of cumulative differences in the molecular make-up of individuals; these he ascribed not to climate or to diet, but to chance errors in the composition of the seminal fluid of the parents. Cf. below, section L, note 100.

26 Diderot's lively interest in the sexual behaviour of women is apparent not only in his own personal history, but also in novels such as *Les Bijoux indiscrets, La Religieuse* and *Jacques le fataliste,* and short stories such as *Mystification* (1768) and *Madame de La Carlière* (c.1772).

27 This theory had originated with Aristotle's *Physics,* and was still widely held at the time. It had been explained already by Maupertuis in his *Vénus physique* (1745) as well as in his *Dissertatio,* and was taken up by Buffon, as Diderot's note indicates.

28 See *Vénus physique,* chapter XVI.

29 The Classical doctrine of imitation still held sway in many intellectual circles. Contemporary French dictionaries still gave 'genius' as a synonym for 'mind', devoid of any exceptional connotations. Diderot's eulogy of the creative genius was therefore at odds with the hostility often displayed towards creativity.

30 In July 1740, Charles Bonnet's memoir on the parthenogenesis of aphids had been read to the Académie des Sciences in Paris. In 1744, Abraham Trembley had published his celebrated memoir on the fresh-water polyp. Diderot's purpose in referring to them, however obliquely, is to undermine further the belief in the need for God always to intervene in the process of creation or generation.

31 Cf. *Les Bijoux indiscrets,* I, chapter XXIX, which deals with the value of scientific hypotheses.

32 Cf. Sections V and VI above.

33 Diderot had already shown his contempt for the ignorant, unlettered section of the population in section LIII of the *Philosophical Thoughts.* In his later years, as his political writings would show, he was to become more sympathetic towards the great mass of citizens, regarding them as downtrodden and repressed by tyranny. See Anthony R Strugnell, *Diderot's Politics* (The Hague, M. Nijhoff, 1973).

34 'Rational' is used here in the sense of 'concerned with what exists in the mind', as opposed to what exists in nature.

35 The Book of Daniel (II, v. 32) refers to a monster with feet of clay seen by Nebuchadnezzar in a dream; it is destroyed by a stone 'cut out by no human hand.' Diderot's slight modification of the Biblical text again reduces the role of God.

36 Diderot develops the ideas sketched out by Bacon in Book V, chapter IV of *The Advancement and Proficiencie of Learning,* and Book I of the *Novum Organum;* in Bacon's view, the *Idolæ,* or received ideas, prevent men from acquiring a true knowledge of nature.

37 Archimedes was reputed to have said that, with his knowledge of mechanics, if he were given a place to stand he could move the world.

38 Isaac Newton had first set out the results of his experiments with the prism in *A new theory about light and colours* in 1662, though his major work in the field, the *Opticks,* did not appear until 1704. It was translated into French in 1720 by Pierre Coste (cf. note 21).

39 This division of the natural sciences is based very loosely on the scheme set out by Bacon as early as 1603 in Book III of *The Advancement and Proficiencie of Learning.*

40 An ironic reference to the 'preparation of the soul' required of devout believers, who are obliged to accept assertions founded not on experiment, but on dogma.

41 'Have Laïs, so long as Laïs does not have you.' This was, by tradition, the response given by Aristippus of Cyrenæ to those who criticised him for frequenting the prostitute Laïs. The story is also recounted in Diderot's article 'Cyrénaïque' in volume IV of the *Encyclopédie* published in 1754.

42 The story related in this and the following sections was one of Æsop's *Fables;* it was retold by La Fontaine in his own *Fables,* which were first published in 1669. These earlier versions draw the conclusion that work is its own reward, and make no mention of any lead-mine; this detail was added by Diderot to underscore the importance of developing the mineral wealth of France, and the need for co-operation between like-minded seekers after truth.

43 An echo of the practice adopted by Diderot as editor of the *Encyclopédie:* it was his custom to visit the workshops of the various craftsmen whose activities are described in the work, and to record their trades as carefully as any other subject. Many of the plates accompanying the text depict such humble toil in detail.

44 The germ of this idea is in *The Advancement and Proficiencie of Learning*, Book III, chapter V, though Bacon condemns the 'monstrous apparitions' produced by irrational beliefs. The passage is significant as an anticipation of the scientific importance of dreams to be discussed in *D'Alembert's Dream*.

45 Diderot is referring to what eighteenth-century doctors called a 'false conception', or what would now be called an ectopic pregnancy. The sac (known today as a blastotocyst, or blastoderm) contains some parts of a normal fœtus, but has no placenta, and is attached directly to the womb. As is confirmed by contemporary sources such as John Memis' *The Midwife's Pocket-Companion* (1765), medical science at that time was unable to say unequivocally whether the mola was formed spontaneously or by sexual activity. The length and technical complexity of this and other articles in this series of 'conjectures' make them similar to entries in the *Encyclopédie*. Indeed, the article 'Mole', by the surgeon Louis, which appeared in 1765 (X, 626–27), quotes at length from this section of the *Interpretation*, and refers the reader to it.

46 Here again, as in the *Letter on Blindness*, Diderot stresses the point that 'monsters' are engendered by nature, and obey the laws of nature. His purpose is not only to communicate his view that nature encompasses all of creation, but also to undermine the credulous belief in 'unnatural' diabolical creatures, such as those with which the Church frightened the faithful into compliance with its doctrines. The (unsigned) article 'Licorne' in the *Encyclopédie* gives similarly short shrift to the belief in fabulous creatures such as the unicorn.

47 The same idea was expressed by Buffon in the chapter of the *Natural History* devoted to the formation of the fœtus.

48 Buffon, in his *Theory of the Earth*, which is to be found in Book I of the *Natural History*.

49 Much of this section derives directly from the article on the aurora borealis in volume I of the *Encyclopédie* (1751), most of which is by Samuel Formey. In an editorial note at the end of the article, d'Alembert had made the same point as Diderot makes here, and had dismissed rather sharply those who ascribed the phenomenon to other causes.

50 This point, too, is made by d'Alembert in the same article.

51 D'Alembert suggests that electrical matter moves towards the north in keeping with the movement of the Earth, and escapes through the poles of a magnet. The link between the aurora and electricity in the northern parts of the globe is, he argues, a matter on which further observations would be of value(*ibid*).

52 Diderot's information on the effects of electricity is derived from various sources; of particular importance are the works of the abbé Nollet, whose *Essai sur l'électricité des corps* had appeared in 1750, and the *Experiments and Observations on Electricity* (1751) by Benjamin Franklin, which had been translated into French in 1752.

53 Diderot is very much of his time in attributing this increase in the weight of lead to the action of fire. This theory relied on the notion that a substance called 'phlogiston', which allegedly existed in all combustible bodies, was released on burning, and combined with the material being burned. It was not challenged until the 1770s, when Lavoisier's experiments began to undermine its credibility.

54 Diderot would have found much of his information on crystals in the (unsigned) articles on the subject written by the Baron d'Holbach for volume IV of the *Encyclopédie* (1754).

55 This is one of the most prescient sections of the whole work, in that it groups together phenomena now known to be caused by changes in the atomic structure

of the objects concerned. Electricity was still generally thought of merely as being induced in bodies by friction, giving them the power to attract other bodies, as when amber is rubbed: this was the definition still offered by the *Dictionnaire de Trévoux* in 1762.

56 The existence of atmospheric electricity had been discussed by Benjamin Franklin in his *Experiments and observations* (1749), and by Pierre-Charles Le Monnier in the first of his *Observations de la lune, du soleil et des étoiles fixes* in 1751. Its existence was not to be conclusively proved until the late nineteenth century, in the work of Linss.

57 That is to say, ice is not a conductor of electricity, but needs friction to induce a current to pass through it, unlike water.

58 Although the meaning of this sentence is not wholly clear, Diderot seems to be suggesting that the ice at the poles is given an electrical charge by the rotation of the earth, which has a vitreous core, and thus creates the magnetism which affects the needle of a compass.

59 Diderot's interest in mechanics had been stimulated by the publication in 1746 of Euler's *De la force de percussion*; he refers to it in the second of the *Mémoires sur différens sujets de mathématiques*(1748), which is an early version of this section of the *Interpretation*. Euler's work was also mentioned in the article 'Cordes (*Méchan.*)' which d'Alembert published in volume IV of the *Encyclopédie* in 1754. It deals with the tension of strings and the laws governing their vibration, as established by Taylor and Bernouilli, with further recent contributions from Euler and from d'Alembert himself. Diderot was therefore raising problems with which the most outstanding mathematicians of the day were also grappling.

60 The same point is made by d'Alembert in 'Cordes'.

61 The attempt to frame the laws of dynamics to cover all types of bodies flies in the face of Cartesian physics, which argued that the matter of which some bodies are composed is less dense than that of other bodies, thus creating different reactions in any given experimental situation. The point is argued in Part II of Descartes' *Principles of Philosophy* (1644).

62 In the *Encyclopédie* article 'Elasticité' (1755) d'Alembert praises this section of the *Conjectures* for being both original and valuable.

63 As so often in this work, Diderot's concern is not so much with arid technicalities as with the wider issue of the general laws of nature, on the consistency of which he insists both at the microcosmic and macrocosmic levels. The underlying guarantee of consistency is no longer, as it was in Descartes' system, the unvarying nature of God, but the nature of matter. One need hardly add that, if order is the consequence of the nature of matter, God is superfluous in the universe as conceived by Diderot.

64 It is to this section that the final *Observation* refers.

65 Diderot's belief in the theory of molecular cohesion to explain the aggregation of matter is as distinctively modern as anything in the *Interpretation*.

66 It is essential to remember that Diderot is not referring to different laws of attraction operating in the universe (since the co-existence of such laws would be incompatible with the unity of nature), but to the laws governing the attraction of certain types of molecules, which obviously vary from one substance to another, producing qualities such as hardness, softness, elasticity, etc. The point is made again at the very end of this section.

67 Cf. Note 53 above.

68 Cf. note 62 above.

69 The caves at Arcy-sur-Cure, not far from Auxerre, had yielded a large number of prehistoric animal remains. Diderot's article 'Arcy' in volume I of the *Encyclopédie* had made many of the points to which he returns, in a different context, in the present work. The subtext to these remarks is the view that the evidence garnered by science invalidated the Biblical account of creation, and was incompatible with the belief that the world was only six thousand years old. See below, note 141.

70 This section of the *Interpretation* is heavily indebted to the *Encyclopédie*, which articulates a deep practical concern for the development of trade and industry. Diderot's article 'Acier' in volume I describes in detail the process of steel-making; extensive additional information is provided in 'Fer' and 'Forge', which were written by other contributors, though they had not appeared by the time the *Interpretation* was published. 'Forge' is one of the most copiously-illustrated in the whole work, with no fewer than 52 plates.

71 Diderot is alluding here to the abbé Nollet and to Rouelle, who, since the 1730s, had been giving popular lectures on physics and chemistry during which they performed experiments. Diderot's own transcription of some of the lectures given by Rouelle which he attended in 1756–58 is reproduced in volume IX of the *Œuvres complètes de Diderot* (Paris, Hermann, 1981), p.215–39.

72 This statement sums up much of the thinking behind the *Encyclopédie*, in which the skills used in many professions and trades are revealed to the public, often for the first time.

73 Newton and Leibniz were credited with having discovered independently of each other the principles of differential calculus. Leibniz was the first to publish his discovery in 1684; Newton's first public disclosure dates from 1687, though he was known to have employed the principle in his work as early as 1669. Diderot seems always to have preferred Newton's claim to that of Leibniz.

74 The *Encyclopédie* article 'Chimie' (by the chemist Venel) states that Georg Ernst Stahl (1660–1734) published the principal ideas his master Johann Joachim Becher (1625–1682) in a style which would repel all but the most learned of readers. The remarks in this section are obviously intended as a reproach to Venel, who approves of Stahl's obscurity, on the grounds that his work might otherwise become as misunderstood in the popular mind as that of Newton.

75 Diderot's assessment of the reception his work was likely to receive was accurate: on its publication, and for years afterwards indeed, the *Interpretation* was dismissed as obscure and incomprehensible.

76 The French text at this point refers to 'l'ouvrage de Frankelin [sic]', but as several works by him had appeared by 1754, it is unclear to which of them Diderot is referring.

77 Cf. *On the Advancement and Proficiencie of Learning*, Book V, chapter II.

78 Cf.above, paragraph 6 of section XXXVI.

79 The need for some system which will allow the investigator to make sense of his results in a wider context is apparent throughout the *Interpretation*, particularly in the emphasis on discovering the general laws of nature.

80 Diderot had dwelt on the dangers of stubbornness in intellectual matters in some of his earlier works, notably the *Philosophical Thoughts* and *La Promenade du Sceptique*.

81 'Analogy' here does not mean a simple comparison, but genuine points of similarity between apparently different classes of objects. The word is used in this sense in the section of the article 'Analogie' dealing with logic and grammar (*Encyclopédie*, volume I), which is signed jointly by Du Marsais and the abbé Yvon.

82 This point is made by Bacon in *The Advancement and Proficiencie of Learning*, Book V, chapter II, with which this section has a number of incidental similarities.

83 This statement makes no sense in the revised edition of 1754:it refers to a portion of section XXXIII which appeared in the 1753 version, and which Diderot then removed. In it, he suggests that an electrical globe should be covered in gold or silver except at the poles, and friction applied while magnetised or unmagnetised needles are suspended above it, to establish whether they align themselves in a particular direction.

84 A syllogism in which one of the premises is assumed but not stated. Despite Diderot's assertion, it is unclear that two different experiments based on the same premise will necessarily lead to results which are identical in all respects.

85 Diderot's desire to discover the underlying unity of nature, and his conviction that such unity must exist, is manifest in this section.

86 As in earlier sections of the *Interpretation*, mathematics is not seen as a way of achieving this perfect state of knowledge; Diderot merely uses it as an analogy to indicate that experimental science should aim as far as possible to achieve the degree of completeness found in mathematical demonstrations.

87 Cf. the end of section X of the *Interpretation*.

88 The importance of chance in experimental science had been stressed by Bacon in the *Advancement*, Book V, chapter II.

89 Bacon had devoted much of Book V, chapter IV of the *Advancement* to a consideration of the *Idolaes [sic]*, or impediments to understanding; among these he includes the '*Idola Theatri, or depraved Theories or Philosophies, and perverse Laws of Demonstrations*.'

90 Diderot uses the word 'méthodistes' to designate Linnæus and his followers. In the *Interpretation*, the term must be taken to mean 'those who classify or arrange according to a particular method or scheme' (OED). This sense was current in English in the mid-eighteenth century, before it became inextricably associated with non-conformist Protestantism.

91 Essentially the same points had already been made by Buffon in the volumes of the *Natural History* devoted to the history of man (1749). The chapters devoted to monkeys in the volumes dealing with the history of quadrupeds (1753–67) contain further reflections on the subject.

92 Carl von Linné (1707–78), known from the latinised form of his name as Linnæus, is regarded as the founder of modern systematic botany; he was the first to lay down the principles for defining genera and species, and to use specific names in a uniform and consistent way. His *Fauna Suecica* appeared in 1746.

93 Diderot reproduces accurately the substance of the preface to the *Fauna*, though he omits Linnæus's eulogy of human reason, which significantly modifies the statements quoted here.

94 See above, Diderot's first note to section XII. The *Dissertatio* to which Diderot alludes here (and from which he sometimes quotes directly) was published in a very small number of copies, and is virtually unobtainable. The French version, the *Essai sur la formation des corps organisés* (1754), which Diderot also uses, was reprinted in a number of editions of Maupertuis' works.

95 This is a reference to the physics of Descartes, as set out in his *Principia philosophiæ [Principles of Philosophy]*(1644).

96 While this may be a reference to the physics of Newton, it could also refer to d'Alembert who, in the article 'Matière' of the *Encyclopédie* (1751), had stated that impenetrability, motility and divisibility are the essential qualities of matter.

97 A direct reference to Newton's *Principia mathematica* (1687).

98 The term 'plastic nature', which was widely used, was taken from the works of two English neo-platonist writers, Henry More's *Enchiridion metaphysicum* (1671) and Ralph Cudworth's *True intellectual system of the universe* (1678). The essence of this doctrine is that it supposes that God is separate from matter, which has its own laws of organisation ordained by Him.

99 A reference to the theory of *emboîtement* or pre-formation which was widely held in the eighteenth century, in opposition to that of epigenesis, or the continuous creation of new organisms.

100 In the edition of his works published in Lyon in 1756, Maupertuis responded somewhat irritably to Diderot's comments on his work, and repudiated the use of the term 'sensitive soul' as irrelevant to his own ideas. Diderot seems to be mixing up the traditional division of the soul into three parts, the sensitive, the rational and the vegetative: the sensitive soul was found only in animals, and was not common to all minds of matter, as he alleges.

101 Any accusation of materialism and atheism would have greatly troubled the devout Maupertuis. In the foreword to his *Essai de Cosmologie* (1750), he maintains that the sheer abundance of the wonders of nature compel belief in God.

102 Diderot is careful to report accurately the substance (and sometimes the actual words) of Maupertuis' *Essai sur la formation des corps organisés.*

103 This is the first occurrence in Diderot's writings of an image to which he will return in *D'Alembert's Dream.* The essence of the idea is to be found in Maupertuis' *Essai.*

104 See above, sections XI and XII. Maupertuis had explained the existence of new species by a succession of chance mutations, and refers to each divergence from the original as an 'error'. Diderot makes no such judgement on the workings of nature. Modern geneticists are inclined, on the basis of DNA evidence, to accept that all life originated in one original act of creation.

105 This is a variation on the problem raised in section XXXVI in relation to the behaviour of molecules in mixed substances.

106 'It appears that when all the perceptions of the elements are brought together, the result is one single perception, which is much stronger and more perfect than any of the elementary perceptions. This perception may stand in the same relationship to these perceptions as the organised body to the element. Once each element has united with the others, has blended its perceptions with theirs, and has lost the feeling of being a particular self, the memory of the primitive state of the elements ceases, and our origins become entirely lost to us.' Diderot's reason for quoting the original Latin of Maupertuis's text is no doubt to avoid accusations of misrepresentation in this crucial matter.

107 This remark fooled nobody, least of all Maupertuis, who, in his reply to Diderot, accused him of wanting to draw exactly these consequences from the *Essai* (see above, note 97).

108 Cf. sections VI and XI above, and section LVIII, question I.

109 This is the crux of Diderot's argument. If the world is effectively the totality of all created things, and God is by definition infinite, then God and the world cannot be separate. This pantheistic outlook goes back to Antiquity, and can be found in the works of the Stoics among others; it had been given a new impetus by the *Ethics* of Spinoza (1677). The Church condemned it as a purely atheistic doctrine. Maupertuis' response was to reject any link with Spinozism in this sense, and to maintain that the universe is not a whole; he does not explore the implications of this denial.

110 Diderot's purpose in analysing Maupertuis' work so closely is apparent here. Maupertuis (1698–1759) had been President of the Royal Academy of Sciences in Berlin, and was celebrated for his pioneering work in astronomy, geometry and the theory of reproduction. He was therefore an important figure in the debate on the nature of the universe, and (no doubt unintentionally) lent considerable weight to the arguments deployed by the relatively unknown Diderot.

111 'Organic molecules' (an expression derived from Buffon) are the elementary parts of living beings, the smallest units capable of sentient life.

112 This is the clearest statement in the *Interpretation* of Diderot's belief that matter is self-organising. It underlies much of what we find elsewhere in the work, and looks forward to the more complex theories put forward in *D'Alembert's Dream* and *Rameau's Nephew.*

113 See above, sections XVIII and XXII.

114 This is a return to the attack on mathematics launched in the early sections of the *Interpretation.* For once, Diderot does not echo Bacon, who extolled the advantages of mathematics in measuring quantities (see *On the Advancement and Proficiencie of Learning,* Book III, chapter VI).

115 Cf. above, sections XXIII, XXXI and XLIII.

116 But see above, section XIII.

117 Diderot may be thinking of Réaumur's *Mémoires pour servir à l'histoire des insectes,* which had been published in six volumes between 1734 and 1742. But he also has in mind, more generally, the 'methodists' whom he had taken to task in sections XLVIII and XLIX.

118 These names are not chosen at random, but are the expression of Diderot's frustration at the hostility attending the publication of any work which challenged ecclesiastical orthodoxy. Montesquieu's *De l'Esprit des Loix [On the Spirit of the Laws]*(1748) had been viciously attacked in the Jansenist periodical *Les nouvelles ecclésiastiques* for its alleged Spinozist tendencies. Its hostile reception had become something of a *cause célèbre* with the encyclopedists, who praised it frequently in various articles. On Montesquieu's death in 1755, a sixteen-page eulogy of him was added to volume V of the *Encyclopédie.* Diderot was the only one of the *Philosophes* to attend his funeral. The *Lettres à un Américain* (1751) by another Jansenist, Lelarge de Lignac, had attacked Buffon's *Natural History.*

119 As this outburst indicates, Diderot himself had not been spared similar criticisms. The *Journal de Trévoux,* a Jesuit publication edited by Guillaume-François Berthier, had repeatedly savaged the *Encyclopédie,* which it saw as a dangerously free-thinking rival to its own *Dictionnaire de Trévoux.* The Jesuits had also been instrumental in securing the suspension of the *Encyclopédie* for several months in 1752; in 1759, following its condemnation by the Pope, it was to be officially suppressed for a number of years. On contemporary reactions to the *Encyclopédie,* see John Lough, *Essays on the* Encyclopédie *of Diderot and D'Alembert* (Oxford, 1968), chapters V and VI.

120 Charles Pinot-Duclos (1704–72) was the Permanent Secretary of the Académie Française, and the author of several novels and works of history.

Jean Le Rond d'Alembert (1717–83) was, in addition to being the co-editor with Diderot of the *Encyclopédie,* perhaps the most outstanding mathematician in Europe at that time.

Jean-Jacques Rousseau (1712–78) had contributed articles on musicology to the *Encyclopédie,* and was already noted for his attacks on the harm done to mankind by the arts and sciences. He was soon to break publicly with Diderot and the

Philosophes, with whose belief in material progress he increasingly disagreed.

François-Marie Arouet de Voltaire (1694–1778) was the leading figure in the *Philosophe* camp; he was mainly known at this time for his tragedies and works of history, including the *Siècle de Louis XIV* (1751), mentioned later in the paragraph.

On Maupertuis, see above, note 110.

In addition to *De l'Esprit des Loix,* Charles-Louis de Secondat, baron de Montesquieu (1689–1755) had written the *Lettres persanes [Persian Letters]* (1721), together with a number of works on the relationship between customs and climate, and on the general influences shaping human conduct.

Georges-Louis Leclerc, comte de Buffon (1707–88) began publishing his monumental *Histoire naturelle* in 1749; the final volumes, completed by other hands, did not appear until 1804.

Louis-Jean-Marie Daubenton (1716–1800) was one of the greatest naturalists and anatomists of his time.

121 In other words, that the universe has no beginning and no end, in contradiction to what is said in the Bible.

122 Saunderson, in the *Letter on the Blind,* makes this point in a different way: because he cannot see them, he refuses to concede that the wonders of nature prove the existence of God. The doctrine that we cannot know that something exists if we have no sensory knowledge of it was the core of Bishop Berkeley's philosophy, as set out in his *Dialogues of Hylas and Philonous* (1713). Diderot had already discussed Berkeley's ideas in *La Promenade du Sceptique* (1747), but had been unable to refute them to his own satisfaction.

123 This description of the approach adopted by the interpreter of nature differs from that of the systematising rationalist: the interpreter uses experimental evidence, rather than reason alone, to take him as far in his investigations as possible; on that basis, he then formulates more general conclusions, stopping only where human knowledge cannot take him, namely into the realms of theology.

124 This rejection of final causes was a hallmark of *Philosophe* thought. In his article 'Causes finales' in volume II of the *Encyclopédie* (1752), d'Alembert had agreed with Bacon that the search for final causes was futile.

125 That is, theology 'based upon reasoning from natural facts apart from revelation' (OED).

126 Hence, any attempt to determine *why* nature operates as it does must inevitably be speculative, and lead use away from the study of *how* it operates, which is the true realm of the natural scientist.

127 Exupère-Joseph Bertin (1712–81) carried out a series of experiments on the lymphatic system and on the blood vessels. In medical science, 'anastomosis' designates communication between two distinct bodily entities of any kind, such as arteries and veins, or, as here, between two different arterial systems. The article on the subject which the Baron de Haller contributed to volume I of the *Encyclopédie* provided Diderot with a wealth of information.

128 'The heavens are telling the glory of God' (Psalms, XIX, v.1).

129 Galen (2nd century AD) long remained the standard source of medical knowledge. His treatise on the human body contained a number of statements which seemed to indicate a finalist interpretation of God's purpose in creating man in His own image. Hermann Boerhaave (1668–1738) was a professor of medicine at Leyden; he was the inspiration behind the 'man is a machine' thesis of his pupil La Mettrie, who translated some of his works into French, though none exists with this title. The Swiss physiologist Albrecht von Haller (1708–77) was also a

pupil of Boerhaave; he secured a European reputation for his research in medicine, botany and anatomy. His major work, the *Elementa physiologiæ corporis humani,* did not begin to appear until 1757, but Diderot may be basing his remarks on his short treatise *Primæ linæ physiologiæ* (1751). Despite Haller's genius for rigorous scientific experimentation, his letters show him to have been a somewhat naïve finalist in religious matters.

130 For Bacon's views on the preconceptions which threaten to deform the judgement, see above, note 89. The attack on 'common sense' had been set out in Descartes' *Discours de la méthode [Discourse on Method]* (1637), in which he comments that it is not enough to have good sense; one must also know how to use it.

131 *Ecclesiastes,* I, 9.

132 A reference to the *Lettres de Leibnitz et de Clarke* (1717), in which Leibniz mentions that a friend of his had tried unsuccessfully to find two exactly similar leaves in a garden. Leibniz had not laid stress on the observer's *perceiving* the leaves to be of the same shade, and Diderot's emphasis derives from his insistence on the importance of sensory observations for the empirical scientist.

133 Cf. above, section L, note 104. It should be noted that Diderot refers only to the process of change taking place over time, and does not venture to explain it; that is to say, he does not consider the causal development of species which lies at the heart of the theory of evolution.

134 In his article 'Goût' ['Taste'] in volume VII of the *Encyclopédie* (1757), Voltaire was to assert that good taste consisted of admiring that which pleased cultivated minds. Diderot's views on taste were to become rather more permissive in later years, particularly when he became interested in art criticism at the end of the 1750s.

135 This was the first of Diderot's works to conclude with questions, and indicates the open-ended, enquiring nature of the *Interpretation.*

136 Diderot refuses consistently to entertain the idea that all creation could have originated from only one type of matter; the development of his thought in this section recalls what was said in section XXXVI, paragraph 5 and 6, on the heterogeneity of matter resulting from the mixing of different kinds of molecules.

137 Science was to echo Diderot's views in this respect for another century or more. In 1884, the OED was still defining an atom as 'a theoretical body, so infinitely small as to be incapable of further division.'

138 Cf. section LVII.

139 Diderot's doubts are the symptom of a perplexity from which he was never wholly to free his mind: is what we see now merely a moment of apparent stasis in the infinite chaos of nature, from which we can draw no conclusions, or does it represent what nature has always been, and will always be, as a result of the operation of its laws? On balance, he inclines to the latter view, but can never wholly rid himself of the former.

140 Prescient thoughts such as this put one in mind of recent debates on the fate of the dinosaurs which, many scientists have argued, mutated into birds as a result of catastrophic environmental changes.

141 As an indication of the boldness of these speculations on the development of species over millions of years, it should be remembered that the Church still accepted the calculation, based on the Bible, that the age of the world was 6,000 years (see Diderot's article 'Age (Mythologie)' in volume I of the *Encyclopédie*). Cf. above, note 69.

142 The division of matter into these two categories, a thesis which Diderot rejects here, is put forward (though not in such stark terms) by Buffon in volume I of his *Natural History* (1749).

143 Although the issues raised here are put forward tentatively in the form of questions, it is clear that Diderot envisages matter as containing its own energy, as self-propelled, and that he rejects the idea that any matter can be truly dead. There is thus no need for God to give any impetus to matter, and the unity of nature in purely material terms is strongly implied. These ideas will be further explored in *D'Alembert's Dream.*

144 The matrix theory had been put forward by Buffon in his volume on the history of animals to explain why each species has a particular form. Despite his insistence that species do not change fundamentally over time, the matrix theory sits uneasily with a belief in the variations produced in individuals as a result of environmental changes (cf. above, note 24): each new variation would require its own matrix, or would imply that each matrix is infinitely variable in unpredictable ways. Even if this somewhat elastic definition of a matrix is accepted, it does not account for the fact, acknowledged by Buffon (in *The Epochs of Nature* in volume I) that the remains of ancient species show that they were generally larger than their modern descendants; such generalised changes, whether due to climate or to diet, would imply a permanent change in the matrix, for which his theories cannot readily account.

145 This problem is closely related to the matters discussed in paragraphs 5 and 6 of section XXXVI.

146 Questions 14 and 15 cannot be answered in the static, fixed terms of Buffon's theories. As Diderot indicates in the closing paragraph, they represent the ultimate theoretical problems which scientists should leave aside until the practical difficulties facing mankind have been dealt with.

147 In arguing that Cartesian philosophy (unlike that of Newton perhaps) is unable to explain the variability of action in a vacuum, Diderot is underlining the inadequacy of traditional physics to cope with the discoveries of modern science. A similar attack on the weaknesses of Cartesian science had already been made by Voltaire in his *Letters concerning the English Nation* (1733), and by d'Alembert in the article 'Cartésianisme' in volume II of the *Encyclopédie* (1752). The article was translated into English as 'Des Cartes' Philosophy', and published in the *Select Essays from the Encyclopedy* (London, 1772), p.316–72.

D'Alembert's Dream