bodies: how a huge flame can be kindled from a tiny spark in a moment <when it falls on a large quantity of powder>, and how great its power is; or how the fixed stars radiate their light <instantly> in every direction over such an enormous distance. In this book I have deduced the causes – which I believe to be quite evident – of these and many other phenomena from principles which are known to all and admitted by all, namely the shape, size, position and motion of particles of matter. And anyone who considers all this will readily be convinced that there are no powers in stones and plants that are so mysterious, and no marvels attributed to sympathetic and antipathetic influences that are so asto- 315
nishing, that they cannot be explained in this way. In short, there is nothing in the whole of nature (nothing, that is, which should be referred to purely corporeal causes, i.e. those devoid of thought and mind) which is incapable of being deductively explained on the basis of these selfsame principles; and hence it is quite unnecessary to add any further principles to the list.

188. *What must be borrowed from [my proposed] treatises on animals and on man in order to complete our knowledge of material things.*

I would not add anything further to this fourth part of the *Principles of Philosophy* if, as I originally planned, I was going on to write two further parts – a fifth part on living things, i.e. animals and plants, and a sixth part on man. But I am not yet completely clear about all the matters which I would like to deal with there, and I do not know whether I shall ever have enough free time to complete these sections. So, to avoid delaying the publication of the first four parts any longer, and to make sure there are no gaps caused by my keeping material back for the two final parts, I shall here add a few observations concerning the objects of the senses. Up till now I have described this earth and indeed the whole visible universe as if it were a machine: I have considered only the various shapes and movements of its parts. But our senses show us much else besides – namely colours, smells, sounds and such-like; and if I were to say nothing about these it might be thought that I had left out the most important part of the explanation of the things in nature.

189. *What sensation is and how it operates.*

It must be realized that the human soul, while informing[1] the entire body, nevertheless has its principal seat in the brain; it is here alone that the

1 Lat. *informare*. Descartes occasionally employs this standard scholastic term, though of course he rejects the Aristotelian account of the soul as the 'form' of the body. The French version has simply 'while being united to the entire body'.

soul not only understands and imagines but also has sensory awareness. Sensory awareness comes about by means of nerves, which stretch like threads from the brain to all the limbs, and are joined together in such a
316 way that hardly any part of the human body can be touched without producing movement in several of the nerve-ends that are scattered around in that area. This movement is then transmitted to the other ends of the nerves which are all grouped together in the brain around the seat of the soul, as I explained very fully in Chapter Four of the *Optics*.[1] The result of these movements being set up in the brain by the nerves is that the soul or mind that is closely joined to the brain is affected in various ways, corresponding to the various different sorts of movements. And the various different states of mind, or thoughts, which are the immediate result of these movements are called sensory perceptions, or in ordinary speech, sensations.

190. *Various kinds of sensation. First, internal sensations, i.e. emotional states of the mind and natural appetites.*

The wide variety in sensations is a result, firstly, of differences in the nerves themselves, and secondly of differences in the sorts of motion which occur in particular nerves. It is not that each individual nerve produces a particular kind of sensation; indeed, there are only seven principal groups of nerves, of which two have to do with internal sensations and five with external sensations. The nerves which go to the stomach, oesophagus, throat, and other internal parts whose function is to keep our natural wants supplied, produce one kind of internal sensation, which is called 'natural appetite' <e.g. hunger and thirst>. The nerves which go to the heart and the surrounding area <including the diaphragm>, despite their very small size, produce another kind of internal sensation which comprises all the disturbances or passions and emotions of the mind such as joy, sorrow, love, hate and so on. For example, when the blood has the right consistency so that it expands in the heart more readily than usual, it relaxes the nerves scattered around
317 the openings, and sets up a movement which leads to a subsequent movement in the brain producing a natural feeling of joy in the mind; and other causes produce the same sort of movement in these tiny nerves, thereby giving the same feeling of joy. Thus, if we imagine ourselves enjoying some good, the act of imagination does not itself contain the feeling of joy, but it causes the spirits[2] to travel from the brain to the muscles in which these nerves are embedded. This causes the openings of

1 *Optics*, above pp. 164ff; Cf. *Treatise on Man*, above pp. 100ff; *Passions*, below pp. 340ff.

2 I.e. the so-called 'animal spirits'; Cf. *Passions*, below, pp. 330ff.

the heart to expand, and this in turn produces the movement in the tiny nerves of the heart which must result in the feeling of joy. In the same way, when we hear good news, it is first of all the mind which makes a judgement about it and rejoices with that intellectual joy which occurs without any bodily disturbance and which, for that reason, the Stoics allowed that the man of wisdom could experience <although they required him to be free of all passion>. But later on, when the good news is pictured in the imagination, the spirits flow from the brain to the muscles around the heart and move the tiny nerves there, thereby causing a movement in the brain which produces in the mind a feeling of animal joy. Or again, if the blood is too thick and flows sluggishly into the ventricles of the heart and does not expand enough inside it, it produces a different movement in the same small nerves around the heart; when this movement is transmitted to the brain it produces a feeling of sadness in the mind, although the mind itself may perhaps not know of any reason why it should be sad. And there are several other causes capable of producing the same feeling <by setting up the same kind of movement in these nerves.> Other movements in these tiny nerves produce different emotions such as love, hatred, fear, anger and so on; I am here thinking of these simply as emotions or passions of the soul, that is, as confused thoughts, which the mind does not derive from itself alone but experiences as a result of something happening to the body with which it is closely conjoined. These emotions are quite different in kind from the distinct thoughts which we have concerning what is to be embraced or desired or shunned. The same applies to the natural appetites such as hunger and thirst which depend on the nerves of the stomach, throat and 318
so forth: they are completely different from the volition to eat, drink and so on. But, because they are frequently accompanied by such volition or appetition, they are called appetites.

191. *The external senses. First, the sense of touch.*

As far as the external senses are concerned, five are commonly listed corresponding to the five kinds of objects stimulating the sensory nerves, and the five kinds of confused thoughts which the resulting motions produce in the soul. First of all there are the nerves terminating in the skin all over the body.[1] These nerves may be touched, via the skin, by various external bodies; and these bodies, though remaining intact, stimulate the nerves in various different ways – in one way by their hardness, in another way by their heaviness, in another way by their heat,

1 'First there is the sense of touch, which has as its object all the bodies which can move some part of the flesh or skin of our body, and has as its organ all the nerves which are found in this part of the body and move with it' (French version).

in another way by their humidity, and so on. Corresponding to the different ways in which the nerves are moved, or have their normal motion checked, various different sensations are produced in the mind; and this is how the various tactile qualities get their names. <We call these qualities hardness, heaviness, heat, humidity and so on, but all that is meant by these terms is that the external bodies possess what is required to bring it about that our nerves excite in the soul the sensations of hardness, heaviness, heat etc.>. Moreover, when the nerves are stimulated with unusual force, but without any damage being occasioned to the body, a pleasurable sensation arises <which is a confused thought in the soul and> which is naturally agreeable to the mind because it is a sign of robust health in the body with which it is closely conjoined <in so far as it can undergo the action causing the pleasure without being damaged>. But if there is some bodily damage, there is a sensation of pain <in the soul, even though the action causing the pain may be only marginally more forceful>. This explains why bodily pleasure and pain arise from such very similar objects, although the sensations are completely opposite.

192. *Taste.*
Then there <is the least subtle sense after that of touch, namely taste. Its organs> are other nerves scattered through the tongue and neighbouring areas. The same external bodies, this time split up into particles and floating in the saliva from the mouth, stimulate these nerves in various ways corresponding to their many different shapes <sizes or movements>, and thus produce the sensations of various tastes.

193. *Smell.*
Thirdly, there <is the sense of smell. Its organs> are two other nerves (or appendages to the brain, since they do not go outside the skull) which are
319 stimulated by separate particles of the same bodies that float in the air. The particles in question cannot be of any kind whatsoever: they must be sufficiently light and energetic to be drawn into the nostrils and through the pores of the so-called spongy bone, thus reaching the two nerves. The various movements of the nerves produce the sensations of various smells.

194. *Hearing.*
Fourthly, there <is hearing, whose object is simply various vibrations in the ear. For there> are two other nerves, found in the inmost chambers of the ears, which receive tremors and vibrations from the whole body of surrounding air. When the air strikes the tympanic membrane it produces a disturbance in the little chain of three small bones attached to it; and

the sensations of different sounds arise from the various different movements in these bones.

195. *Sight*

Finally, there are the optic nerves <which are the organs of the most subtle of all the senses, that of sight>. The extremities of these nerves, which make up the coating inside the eye called the retina, are moved not by air or any external bodies entering the eye, but simply by globules of the second element <which pass through the pores and all the fluids and transparent membranes of the eye>. This is the origin of the sensations of light and colours, as I have already explained adequately in the *Optics* and *Meteorology*.[1]

196. *The soul has sensory awareness only in so far as it is in the brain.*

There is clear proof that the soul's sensory awareness, via the nerves, of what happens to the individual limbs of the body does not come about in virtue of the soul's presence in the individual limbs, but simply in virtue of its presence in the brain <or because the nerves by their motions transmit to it the actions of external objects which touch the parts of the body where the nerves are embedded>. Firstly, there are various diseases which affect only the brain but remove or interfere with all sensation. Again, sleep occurs only in the brain, yet every day it deprives us of a great part of our sensory faculties, though these are afterwards restored on waking. Next, when the brain is undamaged, if there is an obstruction in the paths by which the nerves reach the brain from the external limbs, 320
this alone is enough to destroy sensation in those limbs. Lastly, we sometimes feel pain in certain limbs even though there is nothing to cause pain in the limbs themselves; the cause of the pain lies in the other areas through which the nerves travel in their journey from the limbs to the brain. This last point can be proved by countless observations, but it will suffice to mention one here. A girl with a seriously infected hand used to have her eyes bandaged whenever the surgeon visited her, to prevent her being upset by the surgical instruments. After a few days her arm was amputated at the elbow because of a creeping gangrene, and wads of bandages were put in its place so that she was quite unaware that she had lost her arm. However she continued to complain of pains, now in one then in another finger of the amputated hand. The only possible reason for this is that the nerves which used to go from the brain down to the hand now terminated in the arm near the elbow, and were being agitated

1 Cf. *Optics*, above pp. 167ff.

by the same sorts of motion as must previously have been set up in the hand, so as to produce in the soul, residing in the brain, the sensation of pain in this or that finger. <And this shows clearly that pain in the hand is felt by the soul not because it is present in the hand but because it is present in the brain.>

197. *The nature of the mind is such that various sensations can be produced in it simply by motions in the body.*

It can also be proved that the nature of our mind is such that the mere occurrence of certain motions in the body can stimulate it to have all manner of thoughts which have no likeness to the movements in question. This is especially true of the confused thoughts we call sensations or feelings. For we see that spoken or written words excite all sorts of thoughts and emotions in our minds. With the same paper, pen
321 and ink, if the tip of the pen is pushed across the paper in a certain way it will form letters which excite in the mind of the reader thoughts of battles, storms and violence, and emotions of indignation and sorrow; but if the movements of the pen are just slightly different they will produce quite different thoughts of tranquillity, peace and pleasure, and quite opposite emotions of love and joy. It may be objected that speech or writing does not immediately excite in the mind any emotions, or images of things apart from the words themselves; it merely occasions various acts of understanding which afterwards result in the soul's constructing within itself the images of various things. But what then will be said of the sensations of pain and pleasure? A sword strikes our body and cuts it; but the ensuing pain is completely different from the local motion of the sword or of the body that is cut – as different as colour or sound or smell or taste. We clearly see, then, that the sensation of pain is excited in us merely by the local motion of some parts of our body in contact with another body; so we may conclude that the nature of our mind is such that it can be subject to all the other sensations merely as a result of other local motions.

198. *By means of our senses we apprehend nothing in external objects beyond their shapes, sizes and motions.*

Moreover, we observe no differences between the various nerves which would support the view that different nerves allow different things to be transmitted to the brain from the external sense organs; indeed, we are not entitled to say that anything reaches the brain except for the local motion of the nerves themselves. And we see that this local motion produces not only sensations of pain and pleasure but also those of light
322 and sound. If someone is struck in the eye, so that the vibration of the

blow reaches the retina, this will cause him to see many sparks of flashing light, yet the light is not outside his eye. And if someone puts a finger in his ear he will hear a throbbing hum which comes simply from the movement of air trapped in the ear. Finally, let us consider heat and other qualities perceived by the senses, in so far as those qualities are in objects, as well as the forms of purely material things, for example the form of fire: we often see these arising from the local motion of certain bodies and producing in turn other local motions in other bodies. Now we understand very well how the different size, shape and motion of the particles of one body can produce various local motions in another body. But there is no way of understanding how these same attributes (size, shape and motion) can produce something else whose nature is quite different from their own – like the substantial forms and real qualities which many <philosophers> suppose to inhere in things; and we cannot understand how these qualities or forms could have the power subsequently to produce local motions in other bodies. Not only is all this unintelligible, but we know that the nature of our soul is such that different local motions are quite sufficient to produce all the sensations in the soul. What is more, we actually experience the various sensations as they are produced in the soul, and we do not find that anything reaches the brain from the external sense organs except for motions of this kind. In view of all this we have every reason to conclude that the properties in external objects to which we apply the terms light, colour, smell, taste, sound, heat and cold – as well as the other tactile qualities and even what are called 'substantial forms' – are, so far as we can see, simply various 323
dispositions in those objects[1] which make them able to set up various kinds of motions in our nerves <which are required to produce all the various sensations in our soul>.

199. *There is no phenomenon of nature which has been overlooked in this treatise.*

A simple enumeration will make it clear that there is no phenomenon of nature which I have omitted to consider in this treatise. For a list of natural phenomena cannot include anything which is not apprehended by the senses. Now I have given an account of the various sizes, shapes and motions which are to be found in all bodies; and apart from these the only things which we perceive by our senses as being located outside us are light, colour, smell, taste, sound and tactile qualities. And I have just demonstrated that these are nothing else in the objects – or at least we cannot apprehend them as being anything else – but certain dispositions depending on size, shape and motion. <So the entire visible world, in so

1 '... in the shapes, sizes, positions and movements of their parts' (French version).

far as it is simply visible or perceivable by the senses, contains nothing apart from the things I have given an account of here.>

200. *I have used no principles in this treatise which are not accepted by everyone; this philosophy is nothing new but is extremely old and very common.*

I should also like it to be noted that in attempting to explain the general nature of material things I have not employed any principle which was not accepted by Aristotle and all other philosophers of every age. So this philosophy is not new, but the oldest and most common of all. I have considered the shapes, motions and sizes of bodies and examined the necessary results of their mutual interaction in accordance with the laws of mechanics, which are confirmed by reliable everyday experience. And who has ever doubted that bodies move and have various sizes and shapes, and that their various different motions correspond to these differences in size and shape; or who doubts that when bodies collide bigger bodies are divided into many smaller ones and change their shapes? We detect these facts not just with one sense but several – sight, touch and hearing; and they can also be distinctly imagined and
324 understood by us. But the same cannot be said of the other characteristics like colour, sound and the rest, each of which is perceived not by several senses but by one alone; for the images of them which we have in our thought are always confused, and we do not know what they really are.

201. *There are corporeal particles which cannot be perceived by the senses.*

I do consider, however, that there are many particles in each body which are <so small that they are> not perceived with any of our senses; and this may not meet with the approval of those who take their own senses as the measure of what can be known. <But to desire that our human reasoning should go no further than what we can see is, I think, to do it a great injustice.> Yet who can doubt that there are many bodies so minute that we do not detect them by any of our senses? One simply has to consider something which is slowly growing or shrinking and ask what it is that is being added or taken away hour by hour. A tree grows day by day; and it is unintelligible to suppose that it gets bigger than it was before unless we understand there to be some body which is added to it. But who has ever detected with the senses the minute bodies that are added to a growing tree in one day? It must be admitted, at least by those <philosophers> who accept that quantity is indefinitely divisible, that its parts could be made so tiny as to be imperceptible by any of the senses. And it certainly should not be surprising that we are unable to perceive very minute bodies