be just as we now see them. And their nature is much easier to conceive if we see them develop gradually in this way than if we consider them only in their completed form.

From the description of inanimate bodies and plants I went on to describe animals, and in particular men. But I did not yet have sufficient knowledge to speak of them in the same manner as I did of the other things – that is, by demonstrating effects from causes and showing from what seeds and in what manner nature must produce them. So I contented myself with supposing that God formed the body of a man
46 exactly like our own both in the outward shape of its limbs and in the internal arrangement of its organs, using for its composition nothing but the matter that I had described. I supposed, too, that in the beginning God did not place in this body any rational soul or any other thing to serve as a vegetative or sensitive soul, but rather that he kindled in its heart one of those fires without light which I had already explained, and whose nature I understood to be no different from that of the fire which heats hay when it has been stored before it is dry, or which causes new wine to seethe when it is left to ferment from the crushed grapes. And when I looked to see what functions would occur in such a body I found precisely those which may occur in us without our thinking of them, and hence without any contribution from our soul (that is, from that part of us, distinct from the body, whose nature, as I have said previously, is simply to think). These functions are just the ones in which animals without reason may be said to resemble us. But I could find none of the functions which, depending on thought, are the only ones that belong to us as men; though I found all these later on, once I had supposed that God created a rational soul and joined it to this body in a particular way which I described.

But so that you might see how I dealt with this subject, I shall give my explanation of the movement of the heart and the arteries. Being the first and most widespread movement that we observe in animals, it will
47 readily enable us to decide how we ought to think about all the others. But first, so there may be less difficulty in understanding what I shall say, I should like anyone unversed in anatomy to take the trouble, before reading this, to have the heart of some large animal with lungs dissected before him (for such a heart is in all respects sufficiently like that of a man), and to be shown the two chambers or cavities which are present in it. First, there is the cavity on the right, to which two very large tubes are connected: these are the vena cava, which is the principal receptacle of the blood and is like the trunk of a tree of which all the other veins of the body are the branches; and the arterial vein (ill-named because it is really an artery), which originates in the heart and after leaving it divides into

many branches that spread throughout the lungs. Then there is the cavity on the left, likewise connected to two tubes which are as large as the others or even larger: the venous artery (also ill-named because it is nothing but a vein), which comes from the lungs where it is divided into many branches intertwined with those of the arterial vein and with those of the windpipe (as it is called) through which the air we breathe enters; and the great artery which goes out from the heart and sends its branches throughout the body. I should also like the reader to be shown the eleven little membranes which, like so many little doors, open and close the four
openings within these two cavities. Three are situated at the entrance to 48
the vena cava in such a way that they cannot prevent the blood contained in it from flowing into the right-hand cavity, and yet they effectively prevent it from flowing out. Three at the entrance to the arterial vein do just the opposite, readily permitting the blood in the right-hand cavity to pass into the lungs, but not permitting the blood in the lungs to return into it. Likewise two others at the entrance to the venous artery allow the blood in the lungs to flow into the left-hand cavity of the heart, but block its return; and three at the entrance to the great artery permit blood to leave the heart but prevent it from returning. There is no need to seek any reason for the number of these membranes beyond the fact that the opening to the venous artery, being oval because of its location, can easily be closed with two of them, whereas the other openings, being round, can be closed more effectively with three. I should like the reader also to observe that the great artery and the arterial vein have a much harder and firmer composition than the venous artery and the vena cava, and that the latter widen out before entering the heart to form two pouches, called the auricles, which are composed of flesh similar to that of the heart. He will observe that there is always more heat in the heart than in any other place in the body, and finally, that this heat is capable
of causing a drop of blood to swell and expand as soon as it enters a 49
cavity of the heart, just as liquids generally do when they are poured drop by drop into some vessel which is very hot.

After that, I need say little in order to explain the movement of the heart. When its cavities are not full of blood, some blood necessarily flows from the vena cava into the right-hand cavity and from the venous artery into the left-hand cavity, for these two vessels are always full of blood and their entrances, which open into the heart, cannot be blocked. But as soon as two drops of blood have entered the heart in this way, one in each of its cavities, these drops, which must be very large because the openings through which they enter are very wide and the vessels from which they come are very full of blood, are rarefied and expand because of the heat they find there. In this way they make the whole heart swell,

and they push against and close the five little doors at the entrance to the two vessels from which they come, thus preventing any more blood from descending to the heart. Continuing to become more and more rarefied, they push open the six other little doors at the entrance to the other two vessels, going out through them and thereby causing all the branches of the arterial vein and of the great artery to swell almost at the same instant as the heart. Immediately afterwards, the heart contracts, as do these arteries as well, because the blood that entered them grows cold, and their six little doors close again while the five doors of the vena cava and
50 the venous artery reopen and allow the passage of two further drops of blood, which immediately makes the heart and the arteries swell, exactly as before. And it is because the blood thus entering the heart passes through the two pouches called the auricles that their movement is contrary to that of the heart, and they contract when it swells. Now those who are ignorant of the force of mathematical demonstrations and unaccustomed to distinguishing true reasons from probable may be tempted to reject this explanation without examining it. To prevent this, I would advise them that the movement I have just explained follows from the mere arrangement of the parts of the heart (which can be seen with the naked eye), from the heat in the heart (which can be felt with the fingers), and from the nature of the blood (which can be known through observation). This movement follows just as necessarily as the movement of a clock follows from the force, position, and shape of its counterweights and wheels.

One may ask, however, why the blood in the veins is not used up as it flows continually into the heart, and why the arteries are never too full of blood, since all the blood that passes through the heart flows through them. To this I need give no reply other than that already published by an English physician, who must be praised for having broken the ice on this subject.[1] He is the first to teach that there are many small passages at the extremities of the arteries, through which the blood they receive from the heart enters the small branches of the veins, from there going immediately back to the heart, so that its course is nothing but a
51 perpetual circulation. He proves this very effectively by reference to the normal practice of surgeons, who bind an arm moderately tightly above a vein they have opened, so as to make the blood flow out more abundantly than if they had not bound the arm. But just the opposite happens if they bind the arm below, between the hand and the opening, or even if they bind it very tightly above the opening. For it is obvious that a moderately tight tourniquet can prevent the blood that is already

1 William Harvey (1578–1657), whose book on the circulation of the blood, *De Motu Cordis*, was published in 1628 and read by Descartes in 1632.

in the arm from returning to the heart through the veins, but does not prevent fresh blood from coming through the arteries. There are two reasons for this: first, the arteries are situated below the veins and their walls are harder and hence less easily compressed; and second, the blood which comes from the heart tends to flow through the arteries to the hand with more force than it does in returning to the heart through the veins. And since this blood comes out of the arm through an opening in one of the veins, there must necessarily be some passages below the tourniquet (that is, towards the extremity of the arm) through which it may flow from the arteries. Harvey also proves very soundly what he says about the circulation of the blood by pointing to certain small membranes which are arranged in various places along the veins in such a way that they do not permit the blood to pass from the middle of the body towards the extremities but only let it return from the extremities towards the heart. He proves his theory, moreover, by an experiment which shows that all the blood in the body can flow out of it in a very short time through a single artery, even if the artery is tightly bound close
to the heart and cut between the heart and the tourniquet so that no one 52
could have any reason to imagine that the blood drained off comes from anywhere but the heart.

But there are many other facts which prove that the true cause of this movement of the blood is the one I have given.[1] First, there is the difference we see between the blood which flows from the veins and that which flows from the arteries. This can result only from the fact that the blood is rarefied and, as it were, distilled in passing through the heart, and is therefore thinner, livelier and warmer just after leaving it (that is, when in the arteries) than a little before entering it (that is, when in the veins). And if you look closely you will find this difference to be more evident near the heart than in places further from it. Then there is the hardness of the membranes of which the arterial vein and the great artery are composed: this shows well enough that the blood strikes against them with more force than against the veins. And why should the left-hand cavity of the heart and the great artery be larger and wider than the right-hand cavity and the arterial vein, if not because the blood in the venous artery, having been only in the lungs after passing through the heart, is thinner and more easily rarefied than that which comes immediately from the vena cava? And what could physicians learn by feeling the pulse if they did not know that, as the nature of the blood changes, it can be rarefied by the heat of the heart more or less strongly, and more or less quickly, than before? And if we examine how this heat is

1 See *Description of the Human Body* (below, pp. 316ff) for Descartes' criticism of Harvey's explanation of the movement of the blood.

communicated to the other parts of the body, must we not acknowledge
53 that this happens by means of the blood, which is reheated in passing through the heart and spreads from there through the whole body? So it is that if we remove the blood from some part of the body, we thereupon remove the heat as well; and even if the heart were as hot as glowing iron, it would not be able to reheat the feet and the hands as it does unless it continually sent new blood to these parts. Then, too, we know from this that the true function of respiration is to bring enough fresh air into the lungs to cause the blood entering there from the right-hand cavity of the heart, where it has been rarefied and almost changed into vapours, to thicken immediately into blood again before returning to the left-hand cavity. For if this did not happen the blood would not be fit to serve as fuel for the fire in the heart. This is confirmed by seeing that animals without lungs have only one cavity in their hearts, and that unborn children, who cannot use their lungs while enclosed within their mother's womb, have an opening through which blood flows from the vena cava into the left-hand cavity of the heart, and a tube through which blood comes from the arterial vein into the great artery without passing through the lungs. Again, how would digestion take place in the stomach if the heart did not send heat there through the arteries, together with some of the most fluid parts of the blood which help to dissolve the food we have put there? And is it not easy to understand the action that converts the juice of this food into blood, if we consider that the blood passing in and out of the heart is distilled perhaps more than one or two
54 hundred times each day? Again, what more do we need in order to explain nutrition and the production of the various humours present in the body? We need only say that as the blood is rarefied it flows with such force from the heart towards the extremities of the arteries that some of its parts come to rest in parts of the body where they drive out and displace other parts of the blood; and certain parts of the blood flow to some places rather than others according to the situation, shape, or minuteness of the pores that they encounter, just as sieves with holes of various sizes serve to separate different grains from each other. But the most remarkable of all these facts is the generation of the animal spirits: like a very fine[1] wind, or rather a very pure and lively flame, they rise continuously in great abundance from the heart into the brain, passing from there through the nerves to the muscles and imparting movement to all the parts of the body. The parts of the blood which are the most agitated and penetrating, and hence the best suited to compose these spirits, make their way to the brain rather than elsewhere. For this we

1 See footnote 2, p. 100 above.

need suppose no cause other than the fact that they are carried there by the arteries which come most directly from the heart. For according to the laws of mechanics, which are identical with the laws of nature, when many things tend to move together towards a place where there is not enough room for all of them (as when the parts of blood coming from the
left-hand cavity of the heart all tend towards the brain), the weakest and 55
least agitated must be pushed aside by the strongest, which thus arrive at that place on their own.

I explained all these matters in sufficient detail in the treatise I previously intended to publish.[1] And then I showed what structure the nerves and muscles of the human body must have in order to make the animal spirits inside them strong enough to move its limbs – as when we see severed heads continue to move about and bite the earth although they are no longer alive. I also indicated what changes must occur in the brain in order to cause waking, sleep and dreams; how light, sounds, smells, tastes, heat and the other qualities of external objects can imprint various ideas on the brain through the mediation of the senses; and how hunger, thirst, and the other internal passions can also send their ideas there. And I explained which part of the brain must be taken to be the 'common' sense,[2] where these ideas are received; the memory, which preserves them; and the corporeal imagination, which can change them in various ways, form them into new ideas, and, by distributing the animal spirits to the muscles, make the parts of this body move in as many different ways as the parts of our bodies can move without being guided by the will, and in a manner which is just as appropriate to the objects of the senses and the internal passions. This will not seem at all strange to those who know how many kinds of automatons, or moving
machines, the skill of man can construct with the use of very few parts, in 56
comparison with the great multitude of bones, muscles, nerves, arteries, veins and all the other parts that are in the body of any animal. For they will regard this body as a machine which, having been made by the hands of God, is incomparably better ordered than any machine that can be devised by man, and contains in itself movements more wonderful than those in any such machine.

I made special efforts to show that if any such machines had the organs and outward shape of a monkey or of some other animal that lacks reason, we should have no means of knowing that they did not possess entirely the same nature as these animals; whereas if any such machines bore a resemblance to our bodies and imitated our actions as closely as possible for all practical purposes, we should still have two very certain

1 See footnote p. 132, above.
2 Cf. *Rules*, above p. 41, and *Treatise on Man*, above pp. 104ff.

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