ON THE GAIT OF ANIMALS

by Aristotle

translated by A. S. L. Farquharson

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WE have now to consider the parts which are useful to animals for movement in place (locomotion); first, why each part is such as it is and to what end they possess them; and second, the differences between these parts both in one and the same creature, and again by comparison of the parts of creatures of different species with one another. First then let us lay down how many questions we have to consider.

The first is what are the fewest points of motion necessary to animal progression, the second why sanguineous animals have four points and not more, but bloodless animals more than four, and generally why some animals are footless, others bipeds, others quadrupeds, others polypods, and why all have an even number of feet, if they have feet at all; why in fine the points on which progression depends are even in number.

Next, why are man and bird bipeds, but fish footless; and why do man and bird, though both bipeds, have an opposite curvature of the legs. For man bends his legs convexly, a bird has his bent concavely; again, man bends his arms and legs in opposite directions, for he has his arms bent convexly, but his legs concavely. And a viviparous quadruped bends his limbs in opposite directions to a man's, and in opposite directions to one another; for he has his forelegs bent convexly, his hind legs concavely. Again, quadrupeds which are not viviparous but oviparous have a peculiar curvature of the limbs laterally away from the body. Again, why do quadrupeds move their legs criss-cross?

We have to examine the reasons for all these facts, and others cognate to them; that the facts are such is clear from our Natural History, we have now to ask reasons for the facts.

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At the beginning of the inquiry we must postulate the principles we are accustomed constantly to use for our scientific investigation of nature, that is we must take for granted principles of this universal character which appear in all Nature's work. Of these one is that Nature creates nothing without a purpose, but always the best possible in each kind of living creature by reference to its essential constitution. Accordingly if one way is better than another that is the way of Nature. Next we must take for granted the different species of dimensions which inhere in various things; of these there are three pairs of two each, superior and inferior, before and behind, to the right and to the left. Further we must assume that the originals of movements in place are thrusts and pulls. (These are the essential

place-movements, it is only accidentally that what is carried by another is moved; it is not thought to move itself, but to be moved by something else.)

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After these preliminaries, we go on to the next questions in order.

Now of animals which change their position some move with the whole body at once, for example jumping animals, others move one part first and then the other, for example walking (and running) animals. In both these changes the moving creature always changes its position by pressing against what lies below it. Accordingly if what is below gives way too quickly for that which is moving upon it to lean against it, or if it affords no resistance at all to what is moving, the latter can of itself effect no movement upon it. For an animal which jumps makes its jump both by leaning against its own upper part and also against what is beneath its feet; for at the joints the parts do in a sense lean upon one another, and in general that which pushes down leans upon what is pushed down. That is why athletes jump further with weights in their hands than without, and runners run faster if they swing their arms; there is in extending the arms a kind of leaning against the hands and wrists. In all cases then that which moves makes its change of position by the use of at least two parts of the body; one part so to speak squeezes, the other is squeezed; for the part that is still is squeezed as it has to carry the weight, the part that is lifted strains against that which carries the weight. It follows then that nothing without parts can move itself in this way, for it has not in it the distinction of the part which is passive and that which is active.

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Again, the boundaries by which living beings are naturally determined are six in number, superior and inferior, before and behind, right and left. Of these all living beings have a superior and an inferior part; for superior and inferior is in plants too, not only in animals. And this distinction is one of function, not merely of position relatively to our earth and the sky above our heads. The superior is that from which flows in each kind the distribution of nutriment and the process of growth; the inferior is that to which the process flows and in which it ends. One is a starting-point, the other an end, and the starting-point is the superior. And yet it might be thought that in the case of plants at least the inferior is rather the appropriate starting-point, for in them the superior and inferior are in position other than in animals. Still they are similarly situated from the point of view of function, though not in their position relatively to the universe. The roots are the superior part of a plant, for from them the nutriment is distributed to the growing members, and a plant takes it with its roots as an animal does with its mouth.

Things that are not only alive but are animals have both a front and a back, because they all have sense, and front and back are distinguished by reference to sense. The front is the part in which sense is innate, and whence each thing gets its sensations, the opposite parts are the back.

All animals which partake not only in sense, but are able of themselves to make a change of place, have a further distinction of left and right besides those already enumerated; like the former these are distinctions of function and not of position. The right is that from which change of position naturally begins, the opposite which naturally depends upon this is the left.

This distinction (of right and left) is more articulate and detailed in some than in others. For animals which make the aforesaid change (of place) by the help of organized parts (I mean feet for example, or wings or similar organs) have the left and right distinguished in greater detail, while those which are not differentiated into such parts, but make the differentiation in the body itself and so progress, like some footless animals (for example snakes and caterpillars after their kind, and besides what men call earth-worms), all these have the distinction spoken of, although it is not made so manifest to us. That the beginning of movement is on the right is indicated by the fact that all men carry burdens on the left shoulder; in this way they set free the side which initiates movement and enable the side which bears the weight to be moved. And so men hop easier on the left leg; for the nature of the right is to initiate movement, that of the left to be moved. The burden then must rest on the side which is to be moved, not on that which is going to cause movement, and if it be set on the moving side, which is the original of movement, it will either not be moved at all or with more labour. Another indication that the right is the source of movement is the way we put our feet forward; all men lead off with the left, and after standing still prefer to put the left foot forward, unless something happens to prevent it. The reason is that their movement comes from the leg they step off, not from the one put forward. Again, men guard themselves with their right. And this is the reason why the right is the same in all, for that from which motion begins is the same for all, and has its natural position in the same place, and for this reason the spiral-shaped Testaceans have their shells on the right, for they do not move in the direction of the spire, but all go forward in the direction opposite to the spire. Examples are the murex and the ceryx. As all animals then start movement from the right, and the right moves in the same direction as the whole, it is necessary for all to be alike right-handed. And man has the left limbs detached more than any other animal because he is natural in a higher degree than the other animals; now the right is naturally both better than the left and separate from it, and so in man the right is more especially the right, more dextrous that is, than in other animals. The right then being differentiated it is only reasonable that in man the left should be most movable, and most

detached. In man, too, the other starting-points are found most naturally and clearly distinct, the superior part that is and the front.

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Animals which, like men and birds, have the superior part distinguished from the front are two-footed (biped). In them, of the four points of motion, two are wings in the one, hands and arms in the other. Animals which have the superior and the front parts identically situated are four-footed, many-footed, or footless (quadruped, polypod, limbless). I use the term foot for a member employed for movement in place connected with a point on the ground, for the feet appear to have got their name from the ground under our feet.

Some animals, too, have the front and back parts identically situated, for example, Cephalopods (molluscs) and spiral-shaped Testaceans, and these we have discussed elsewhere in another connexion.

Now there is in place a superior, an intermediate, and an inferior; in respect to place bipeds have their superior part corresponding to the part of the universe; quadrupeds, polypods, and footless animals to the intermediate part, and plants to the inferior. The reason is that these have no power of locomotion, and the superior part is determined relatively to the nutriment, and their nutriment is from the earth. Quadrupeds, polypods, and footless animals again have their superior part corresponding to the intermediate, because they are not erect. Bipeds have theirs corresponding to the superior part of the universe because they are erect, and of bipeds, man par excellence; for man is the most natural of bipeds. And it is reasonable for the starting points to be in these parts; for the starting-point is honourable, and the superior is more honourable than the inferior, the front than the back, and the right than the left. Or we may reverse the argument and say quite well that these parts are more honourable than their opposites just because the starting-points are in them.

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The above discussion has made it clear that the original of movement is in the parts on the right. Now every continuous whole, one part of which is moved while the other remains at rest must, in order to be able to move as a whole while one part stands still, have in the place where both parts have opposed movements some common part which connects the moving parts with one another. Further in this common part the original of the motion (and similarly of the absence of motion) of each of the parts must lie.

Clearly then if any of the opposite pairs of parts (right and left, that is, superior and inferior, before and behind) have a movement of their own, each of them has for common original of its movements the juncture of the parts in question.

Now before and behind are not distinctions relatively to that which sets up its own motion, because in nature nothing has a movement backwards, nor has a moving animal any division whereby it may make a change of position towards its front or back; but right and left, superior and inferior are so distinguished. Accordingly, all animals which progress by the use of distinct members have these members distinguished not by the differences of before and behind, but only of the remaining two pairs; the prior difference dividing these members into right and left (a difference which must appear as soon as you have division into two), and the other difference appearing of necessity where there is division into four.

Since then these two pairs, the superior and inferior and the right and left, are linked to one another by the same common original (by which I mean that which controls their movement), and further, everything which is intended to make a movement in each such part properly must have the original cause of all the said movements arranged in a certain definite position relatively to the distances from it of the originals of the movements of the individual members (and these centres of the individual parts are in pairs arranged coordinately or diagonally, and the common centre is the original from which the animal's movements of right and left, and similarly of superior and inferior, start); each animal must have this original at a point where it is equally or nearly equally related to each of the centres in the four parts described.

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It is clear then how locomotion belongs to those animals only which make their changes of place by means of two or four points in their structure, or to such animals par excellence. Moreover, since this property belongs almost peculiarly to Sanguineous animals, we see that no Sanguineous animal can progress at more points than four, and that if it is the nature of anything so to progress at four points it must of necessity be Sanguineous.

What we observe in the animal world is in agreement with the above account. For no Sanguineous animal if it be divided into more parts can live for any appreciable length of time, nor can it enjoy the power of locomotion which it possessed while it was a continuous and undivided whole. But some bloodless animals and polypods can live a long time, if divided, in each of the severed parts, and can move in the same way as before they were dismembered. Examples are what is termed the centipede and other insects that are long in shape, for even the hinder portion of all these goes on progressing in the same direction as before when they are cut in two.

The explanation of their living when thus divided is that each of them is constructed like a continuous body of many separate living beings. It is plain, too, from what was said above why they are like this. Animals constructed most naturally are made to move at two or four points, and even limbless Sanguinea are no exception. They too move by dint of four points, whereby they achieve progression. They go

forward by means of two flexions. For in each of their flexions there is a right and a left, both before and behind in their flat surface, in the part towards the head a right and a left front point, and in the part towards the tail the two hinder points. They look as if they moved at two points only, where they touch before and behind, but that is only because they are narrow in breadth. Even. in them the right is the sovereign part, and there is an alternate correspondence behind, exactly as in quadrupeds. The reason of their flexions is their great length, for just as tall men walk with their spines bellied (undulated) forward, and when their right shoulder is leading in a forward direction their left hip rather inclined backwards, so that their middle becomes hollow and bellied (undulated), so we ought to conceive snakes as moving in concave curves (undulations) upon the ground. And this is evidence that they move themselves like the quadrupeds, for they make the concave in its turn convex and the convex concave. When in its turn the left of the forward parts is leading, the concavity is in its turn reversed, for the right becomes the inner. (Let the right front point be A, the left B, the right hind C, the left D.)

Among land animals this is the character of the movement of snakes, and among water animals of eels, and conger-eels and also lampreys, in fact of all that have their form snakelike. However, some marine animals of this shape have no fin, lampreys for example, but put the sea to the same use as snakes do both land and water (for snakes swim precisely as they move on the ground). Others have two fins only, for example conger-eels and eels and a kind of cestreus which breeds in the lake of Siphae. On this account too those that are accustomed to live on land, for example all the eels, move with fewer flexions in a fluid than on land, while the kind of cestreus which has two fins, by its flexion in a fluid makes up the remaining points.

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The reason why snakes are limbless is first that nature makes nothing without purpose, but always regards what is the best possible for each individual, preserving the peculiar essence of each and its intended character, and secondly the principle we laid down above that no Sanguineous creature can move itself at more than four points. Granting this it is evident that Sanguineous animals like snakes, whose length is out of proportion to the rest of their dimensions, cannot possibly have limbs; for they cannot have more than four (or they would be bloodless), and if they had two or four they would be practically stationary; so slow and unprofitable would their movement necessarily be.

But every limbed animal has necessarily an even number of such limbs. For those which only jump and so move from place to place do not need limbs for this movement at least, but those which not only jump but also need to walk, finding that movement not sufficient for their purposes, evidently either are better able to progress with even

limbs or cannot otherwise progress at all every animal which has limbs must have an even us for as this kind of movement is effected by part of the body at a time, and not by the whole at once as in the movement of leaping, some of the limbs must in turn remain at rest, and others be moved, and the animal must act in each of these cases with opposite limbs, shifting the weight from the limbs that are being moved to those at rest. And so nothing can walk on three limbs or on one; in the latter case it has no support at all on which to rest the body's weight, in the former only in respect of one pair of opposites, and so it must necessarily fall in endeavouring so to move.

Polypods however, like the Centipede, can indeed make progress on an odd number of limbs, as may be seen by the experiment of wounding one of their limbs; for then the mutilation of one row of limbs is corrected by the number of limbs which remain on either side. Such mutilated creatures, however, drag the wounded limb after them with the remainder, and do not properly speaking walk. Moreover, it is plain that they, too, would make the change of place better if they had an even number, in fact if none were missing and they had the limbs which correspond to one another. In this way they could equalize their own weight, and not oscillate to one side, if they had corresponding supports instead of one section of the opposite sides being unoccupied by a limb. A walking creature advances from each of its members alternately, for in this way it recovers the same figure that it had at first.

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The fact that all animals have an even number of feet, and the reasons for the fact have been set forth. What follows will explain that if there were no point at rest flexion and straightening would be impossible. Flexion is a change from a right line to an arc or an angle, straightening a change from either of these to a right line. Now in all such changes the flexion or the straightening must be relative to one point. Moreover, without flexion there could not be walking or swimming or flying. For since limbed creatures stand and take their weight alternately on one or other of the opposite legs, if one be thrust forward the other of necessity must be bent. For the opposite limbs are naturally of equal length, and the one which is under the weight must be a kind of perpendicular at right angles to the ground.

When then one leg is advanced it becomes the hypotenuse of a right-angled triangle. Its square then is equal to the square on the other side together with the square on the base. As the legs then are equal, the one at rest must bend either at the knee or, if there were any kneeless animal which walked, at some other articulation. The following experiment exhibits the fact. If a man were to walk parallel to a wall in sunshine, the line described (by the shadow of his head> would be not straight but zigzag, becoming lower as he bends, and higher when he stands and lifts himself up.

It is, indeed, possible to move oneself even if the leg be not bent,

in the way in which children crawl. This was the old though erroneous account of the movement of elephants. But these kinds of movements involve a flexion in the shoulders or in the hips. Nothing at any rate could walk upright continuously and securely without flexions at the knee, but would have to move like men in the wrestling schools who crawl forward through the sand on their knees. For the upper part of the upright creature is long so that its leg has to be correspondingly long; in consequence there must be flexion. For since a stationary position is perpendicular, if that which moves cannot bend it will either fall forward as the right angle becomes acute or will not be able to progress. For if one leg is at right angles to the ground and the other is advanced, the latter will be at once equal and greater. For it will be equal to the stationary leg and also equivalent to the hypotenuse of a right-angled triangle. That which goes forward therefore must bend, and while bending one, extend the other leg simultaneously, so as to incline forward and make a stride and still remain above the perpendicular; for the legs form an isosceles triangle, and the head sinks lower when it is perpendicularly above the base on which it stands.

Of limbless animals, some progress by undulations (and this happens in two ways, either they undulate on the ground, like snakes, or up and down, like caterpillars), and undulation is a flexion; others by a telescopic action, like what are called earthworms and leeches. These go forward, first one part leading and then drawing the whole of the rest of the body up to this, and so they change from place to place. It is plain too that if the two curves were not greater than the one line which subtends them undulating animals could not move themselves; when the flexure is extended they would not have moved forward at all if the flexure or arc were equal to the chord subtended; as it is, it reaches further when it is straightened out, and then this part stays still and it draws up what is left behind.

In all the changes described that which moves now extends itself in a straight line to progress, and now is hooped; it straightens itself in its leading part, and is hooped in what follows behind. Even jumping animals all make a flexion in the part of the body which is underneath, and after this fashion make their leaps. So too flying and swimming things progress, the one straightening and bending their wings to fly, the other their fins to swim. Of the latter some have four fins, others which are rather long, for example eels, have only two. These swim by substituting a flexion of the rest of their body for the (missing) pair of fins to complete the movement, as we have said before. Flat fish use two fins, and the flat of their body as a substitute for the absent pair of fins. Quite flat fish, like the Ray, produce their swimming movement with the actual fins and with the two extremes or semicircles of their body, bending and straightening themselves alternately.

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A difficulty might perhaps be raised about birds. How, it may be said, can they, either when they fly or when they walk, be said to move at four points? Now we did not say that all Sanguinea move at four points, but merely at not more than four. Moreover, they cannot as a fact fly if their legs be removed, nor walk without their wings. Even a man does not walk without moving his shoulders. Everything indeed, as we have said, makes a change of place by flexion and straightening, for all things progress by pressing upon what being beneath them up to a point gives way as it were gradually; accordingly, even if there be no flexion in another member, there must be at least in the point whence motion begins, is in feathered (flying) insects at the base of the 'scale-wing', in birds at the base of the wing, in others at the base of the corresponding member, the fins, for instance, in fish. In others, for example snakes, the flexion begins in the joints of the body.

In winged creatures the tail serves, like a ship's rudder, to keep the flying thing in its course. The tail then must like other limbs be able to bend at the point of attachment. And so flying insects, and birds (Schizoptera) whose tails are ill-adapted for the use in question, for example peacocks, and domestic cocks, and generally birds that hardly fly, cannot steer a straight course. Flying insects have absolutely no tail, and so drift along like a rudderless vessel, and beat against anything they happen upon; and this applies equally to sharded insects, like the scarab-beetle and the chafer, and to unsharded, like bees and wasps. Further, birds that are not made for flight have a tail that is of no use; for instance the purple coot and the heron and all water-fowl. These fly stretching out their feet as a substitute for a tail, and use their legs instead of a tail to direct their flight. The flight of insects is slow and frail because the character of their feathery wings is not proportionate to the bulk of their body; this is heavy, their wings small and frail, and so the flight they use is like a cargo boat attempting to make its voyage with oars; now the frailty both of the actual wings and of the outgrowths upon them contributes in a measure to the flight described. Among birds, the peacock's tail is at one time useless because of its size, at another because it is shed. But birds are in general at the opposite pole to flying insects as regards their feathers, but especially the swiftest flyers among them. (These are the birds with curved talons, for swiftness of wing is useful to their mode of life.) The rest of their bodily structure is in harmony with their peculiar movement, the small head, the slight neck, the strong and acute breastbone (acute like the prow of a clipper-built vessel, so as to be well-girt, and strong by dint of its mass of flesh), in order to be able to push away the air that beats against it, and that easily and without exhaustion. The hind-quarters, too, are light and taper again, in order to conform to the movement of the front and not by their breadth to suck the air.

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So much then for these questions. But why an animal that is to stand erect must necessarily be not only a biped, but must also have the superior parts of the body lighter, and those that lie under these heavier, is plain. Only if situated like this could it possibly carry itself easily. And so man, the only erect animal, has legs longer and stouter relatively to the upper parts of his body than any other animal with legs. What we observe in children also is evidence of this. Children cannot walk erect because they are always dwarf-like, the upper parts of their bodies being longer and stouter than the lower. With advancing years the lower increase disproportionately, until the children get their appropriate size, and then and not till then they succeed in walking erect. Birds are hunchbacked yet stand on two legs because their weight is set back, after the principle of horses fashioned in bronze with their forelegs prancing. But their being bipeds and able to stand is above all due to their having the hip-bone shaped like a thigh, and so large that it looks as if they had two thighs, one in the leg before the knee-joint, the other joining his part to the fundament. Really this is not a thigh but a hip, and if it were not so large the bird could not be a biped. As in a man or a quadruped, the thigh and the rest of the leg would be attached immediately to quite a small hip; consequently the whole body would be tilted forward. As it is, however, the hip is long and extends right along to the middle of the belly, so that the legs are attached at that point and carry as supports the whole frame. It is also evident from these considerations that a bird cannot possibly be erect in the sense in which man is. For as it holds its body now the wings are naturally useful to it, but if it were erect they would be as useless as the wings of Cupids we see in pictures. It must have been clear as soon as we spoke that the form of no human nor any similar being permits of wings; not only because it would, though Sanguineous, be moved at more than four points, but also because to have wings would be useless to it when moving naturally. And Nature makes nothing contrary to her own nature.

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We have stated above that without flexion in the legs or shoulders and hips no Sanguineous animal with feet could progress, and that flexion is impossible except some point be at rest, and that men and birds, both bipeds, bend their legs in opposite directions, and further that quadrupeds bend their in opposite directions, and each pair in the opposite way to a man's limbs. For men bend their arms backwards, their legs forwards; quadrupeds their forelegs forwards, their back legs backwards, and in like manner also birds bend theirs. The reason is that Nature's workmanship is never purposeless, as we said above, but everything for the best possible in the circumstances. Inasmuch, therefore, as all creatures which naturally have the power of changing position by the use of limbs, must have one leg stationary with the weight of the body on it, and

when they move forward the leg which has the leading position must be unencumbered, and the progression continuing the weight must shift and be taken off on this leading leg, it is evidently necessary for the back leg from being bent to become straight again, while the point of movement of the leg thrust forward and its lower part remain still. And so the legs must be jointed. And it is possible for this to take place and at the same time for the animal to go forward, if the leading leg has its articulation forwards, impossible if it be backwards. For, if it be forwards, the stretching out of the leg will be while the body is going forwards, but, if the other way, while it is going backwards. And again, if the flexion were backwards, the placing of the foot would be made by two movements and those contrary to one another, one, that is, backwards and one forwards; for in the bending together of the limb the lower end of the thigh would go backwards, and the shin would move the foot forwards away from the flexion; whereas, with the flexion forwards, the progression described will be performed not with contrary motions, but with one forward motion.

Now man, being a biped and making his change of position in the natural way with his two legs, bends them forward for the reasons set forth, but his arms bend backwards reasonably enough. If they bent the opposite way they would be useless for the work of the hands, and for taking food. But quadrupeds which are also viviparous necessarily bend their front legs forwards. For these lead off first when they move, and are also in the forepart of their body. The reason that they bend forward is the same as in the case of man, for in this respect they are like mankind. And so quadrupeds as well as men bend these legs forward in the manner described. Moreover, if the flexion is like this, they are enabled to lift their feet high; if they bent them in the opposite way they would only lift them a little way from the ground, because the whole thigh and the joint from which the shin-bone springs would lie under the belly as the beast moved forward. If, however, the flexion of the hind legs were forwards the lifting of these feet would be similar to that of the forefeet (for the hind legs, too, would in this case have only a little room for their lifting inasmuch as both the thigh and the knee-joint would fall under the position of the belly); but the flexion being backwards, as in fact it is, nothing comes in the way of their progression with this mode of moving the feet. Moreover, it is necessary or at least better for their legs to bend thus when they are suckling their young, with a view to such ministrations. If the flexion were inwards it would be difficult to keep their young under them and to shelter them.

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Now there are four modes of flexion if we take the combinations in pairs. Fore and hind may bend either both backwards, as the figures marked A, or in the opposite way both forwards, as in B, or in converse ways and not in the same direction, as in C where the fore

bend forwards and the hind bend backwards, or as in D, the opposite way to C, where the convexities are turned towards one another and the concavities outwards. Now no biped or quadruped bends his limbs like the figures A or B, but the quadrupeds like C, and like D only the elephant among quadrupeds and man if you consider his arms as well as his legs. For he bends his arms concavely and his legs convexly.

In man, too, the flexions of the limbs are always alternately opposite, for example the elbow bends back, but the wrist of the hand forwards, and again the shoulder forwards. In like fashion, too, in the case of the legs, the hip backwards, the knee forwards, the ankle in the opposite way backwards. And plainly the lower limbs are opposed in this respect to the upper, because the first joints are opposites, the shoulder bending forwards, the hip backwards; wherefore also the ankle bends backwards, and the wrist of the hand forwards.

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This is the way then the limbs bend, and for the reasons given. But the hind limbs move criss-cross with the fore limbs; after the off fore they move the near hind, then the near fore, and then the off hind. The reason is that (a) if they moved the forelegs together and first, the animal would be wrenched, and the progression would be a stumbling forwards with the hind parts as it were dragged after. Again, that would not be walking but jumping, and it is hard to make a continuous change of place, jumping all the time. Here is evidence of what I say; even as it is, all horses that move in this way soon begin to refuse, for example the horses in a religious procession. For these reasons the fore limbs and the hind limbs move in this separate way. Again, (b) if they moved both the right legs first the weight would be outside the supporting limbs and they would fall. If then it is necessary to move in one or other of these ways or criss-cross fashion, and neither of these two is satisfactory, they must move criss-cross; for moving in the way we have said they cannot possibly experience either of these untoward results. And this is why horses and such-like animals stand still with their legs put forward criss-cross, not with the right or the left put forward together at once. In the same fashion animals with more than four legs make their movements; if you take two consecutive pairs of legs the hind move criss-cross with the forelegs; you can see this if you watch them moving slowly. Even crabs move in this way, and they are polypods. They, too, always move criss-cross in whichever direction they are making progress. For in direction this animal has a movement all its own; it is the only animal that moves not forwards, but obliquely. Yet since forwards is a distinction relative to the line of vision, Nature has made its eyes able to conform to its limbs, for its eyes can move themselves obliquely, and therefore after a fashion crabs are no exception but in this sense move forwards.

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Birds bend their legs in the same way as quadrupeds. For their natural construction is broadly speaking nearly the same. That is, in birds the wings are a substitute for the forelegs; and so they are bent in the same way as the forelegs of a quadruped, since when they move to progress the natural beginning of change is from the wings (as in quadrupeds from the forelegs). Flight in fact is their appropriate movement. And so if the wings be cut off a bird can neither stand still nor go forwards.

Again, the bird though a biped is not erect, and has the forward parts of the body lighter than the hind, and so it is necessary (or at least preferable for the standing posture) to have the thigh so placed below the body as it actually is, I mean growing towards the back. If then it must have this situation the flexion of the leg must be backwards, as in the hind legs of quadrupeds. The reasons are the same as those given in the case of viviparous quadrupeds.

If now we survey generally birds and winged insects, and animals which swim in a watery medium, all I mean that make their progress in water by dint of organs of movement, it is not difficult to see that it is better to have the attachment of the parts in question oblique to the frame, exactly as in fact we see it to be both in birds and insects. And this same arrangement obtains also among fishes. Among birds the wings are attached obliquely; so are the fins in water animals, and the feather-like wings of insects. In this way they divide the air or water most quickly and with most force and so effect their movement. For the hinder parts in this way would follow forwards as they are carried along in the yielding medium, fish in the water, birds in the air.

Of oviparous quadrupeds all those that live in holes, like crocodiles, lizards, spotted lizards, freshwater tortoises, and turtles, have their legs attached obliquely as their whole body sprawls over the ground, and bend them obliquely. The reason is that this is useful for ease in creeping into holes, and for sitting upon their eggs and guarding them. And as they are splayed outwards they must of necessity tuck in their thighs and put them under them in order to achieve the lifting of the whole body. In view of this they cannot bend them otherwise than outwards.

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We have already stated the fact that non-sanguineous animals with limbs are polypods and none of them quadrupeds. And the reason why their legs, except the extreme pairs, were necessarily attached obliquely and had their flexions upwards, and the legs themselves were somewhat turned under (bandy-shape) and backwards is plain. In all such creatures the intermediate legs both lead and follow. If then they lay under them, they must have had their flexion both forwards and backwards; on account of leading, forwards; and on account of following, backwards. Now since they have to do both, for this reason their limbs are turned under and bent obliquely, except the two extreme pairs. (These two are more natural in their movement, the

front leading and the back following.) Another reason for this kind of flexion is the number of their legs; arranged in this way they would interfere less with one another in progression and not knock together. But the reason that they are bandy is that all of them or most of them live in holes, for creatures living so cannot possibly be high above the ground.

But crabs are in nature the oddest of all polypods; they do not progress forwards except in the sense explained above, they are the only animals which have more than one pair of leading limbs. The explanation of this is the hardness of their limbs, and the fact that they use them not for swimming but for walking; they always keep on the ground. However, the flexion of the limbs of all polypods is oblique, like that of the quadrupeds which live in holes-for example lizards and crocodiles and most of the oviparous quadrupeds. And the explanation is that some of them in their breeding periods, and some all their life, live in holes.

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Now the rest have bandy legs because they are soft-skinned, but the crayfish is hard-skinned and its limbs are for swimming and not for walking (and so are not bandy). Crabs, too, have their limbs bent obliquely, but not bandy like oviparous quadrupeds and non-sanguineous polypods, because their limbs have a hard and shell-like skin, although they don't swim but live in holes; they live in fact on the ground. Moreover, their shape is like a disk, as compared with the crayfish which is elongated, and they haven't a tail like the crayfish; a tail is useful to the crayfish for swimming, but the crab is not a swimming creature. Further, it alone has its side equivalent to a hinder part, because it has many leading feet. The explanation of this is that its flexions are not forward nor its legs turned in under (bandy). We have given above the reason why its legs are not turned in under, that is the hardness and shell-like character of its integument.

For these reasons then it must lead off with more than one limb, and move obliquely; obliquely, because the flexion is oblique; and with more than one limb, because otherwise the limbs that were still would have got in the way of those that were moving.

Fishes of the flat kind swim with their heads twisted, as one-eyed men walk; they have their natural shape distorted. Web-footed birds swim with their feet; because they breath the air and have lungs they are bipeds, but because they have their home in the water they are webbed; by this arrangement their feet serve them instead of fins. They have their legs too, not like the rest of birds in the centre of their body, but rather set back. Their legs are short, and being set back are serviceable for swimming. The reason for their having short legs is that nature has added to their feet by subtracting from the length of their limbs; instead of length she gives stoutness to the legs and breadth to the feet. Broad feet are more useful than long for pushing away the water when they are swimming.

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There is reason, too, for winged creatures having feet, but fish none. The former have their home in the dry medium, and cannot remain always in mid air; they must therefore have feet. Fish on the contrary live in the wet medium, and take in water, not air. Fins are useful for swimming, but feet not. And if they had both they would be non-sanguineous. There is a broad similarity between birds and fishes in the organs of locomotion. Birds have their wings on the superior part, similarly fish have two pectoral fins; again, birds have legs on their under parts and near the wings; similarly, most fish have two fins on the under parts and near the pectorals. Birds, too, have a tail and fish a tail-fin.

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A difficulty may be suggested as to the movements of molluscs, that is, as to where that movement originates; for they have no distinction of left and right. Now observation shows them moving. We must, I think, treat all this class as mutilated, and as moving in the way in which limbed creatures do when one cuts off their legs, or as analogous with the seal and the bat. Both the latter are quadrupeds but misshapen. Now molluscs do move, but move in a manner contrary to nature. They are not moving things, but are moving if as sedentary creatures they are compared with zoophytes, and sedentary if classed with progressing animals.

As to right and left, crabs, too, show the distinction poorly, still they do show it. You can see it in the claw; the right claw is larger and stronger, as though the right and left sides were trying to get distinguished.

The structure of animals, both in their other parts, and especially in those which concern progression and any movement in place, is as we have now described. It remains, after determining these questions, to investigate the problems of Life and Death.

-THE END-