ON

DEXTRAL PRE-EMINENCE.

BY

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That man has been from time immemorial a right-handed animal, I take to be a matter beyond dispute. The monuments of Assyria and of Egypt, the language of the Bible and other ancient records, as well as the accounts given by travellers in all ages and in all countries, testify to the fact. So strange a phenomenon could not but attract early attention, and there is, perhaps, no feature of our bodily structure for which more numerous explanations have been devised.

To give a list of these would be wearisome and useless, and I shall limit myself to mentioning one or two of the more notable ones, which may be taken as types of the rest. For numerous as the explanations are, they may all be divided into two classes; in the one of which the phenomenon is attributed to differences, quantitative or qualitative, in the blood of the two sides of the body; while in the other a cause is found in a conventional agreement made for convenience between the members of a community, and

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handed down by educational influence from parent to child, through successive generations.

Of the former group Aristotle will supply an example. The right side, said he, is pre-eminent over the left, because it receives, not only a more abundant supply of blood, but blood of a different quality, purer and hotter. For the aorta with its branches supplies the left side, while the vena cava, which is larger than the aorta and lies on its right, supplies the right side of the body.[1] Sir Thomas Browne, on the other hand, dismisses this and all similar explanations alike, and declares that in his opinion the dextral pre-eminence has "no regular or certain root in nature;" that it does not exist in children, and that in adults it is the result of institution, not of nature; "for it is most reasonable for uniformity and sundry respective uses that men should apply themselves to the constant use of one; for there will otherwise arise anomalous disturbances in manual actions, not only in civil and artificial, but also in military affairs and in the several actions of warre."[2] At a later period we find Bichat professing much the same opinion. This anatomist had laid down the law that the instruments of the life of relation are symmetrical, while

[1] I take this opportunity of correcting an error which has somehow crept into the history of physiology and been universally accepted; namely, the statement that it was Galen who first discovered that the arteries during life contain blood, all his predecessors having thought that they contain air. Even Cuvier, the great admirer of Aristotle, attributes to him this erroneous belief. So, also, does Milne-Edwards, who goes so far as to consider why Galen, in his treatise on the contents of the arteries, attacked Erasistratus rather than Aristotle ('Leçons sur la Phys.,' i, 10—11). Yet Aristotle states on several occasions, and with the greatest distinctness, that the arteries as well as the veins contain blood, the blood in the former being of a different quality from that in the latter ('De Partibus Anim.,' iii, 4, 5). He also states that often after death some of the larger vessels *appear* to contain no blood, and accounts for this ('Hist. Anim.,' iii, 2). The mistake has arisen partly from mistranslation of the words φλέψ and ἀρτηρία; of which the former in Aristotle means *blood-vessel*, not *vein*; the latter *windpipe*, not *artery*; and partly from reliance being placed on the treatise 'De Spiritu,' which is most clearly not the work of Aristotle at all, standing not only in its doctrines, but in its language, in strong contrast with the genuine Aristotelian treatises.

[2] 'Vulgar Errors,' iv, 5.

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those of organic life are unsymmetrical. The functional superiority of the right hand over the left seemed opposed to this doctrine. And so Bichat got over the difficulty by asserting that "this discord has no foundation, or next to none, in nature; but is manifestly the result of our social habits." The order of letters in writing, he says, is from left to right, and this circumstance compels us to use the right hand, which is much more adapted for motion in this direction than is the left. So also "la nécessité de l'ensemble dans les combats a determiné à employer généralement la main droite pour saisir les armes; l'harmonique qui dirige la danse des peuples les plus sauvages exige dans les jambes un accord, qu'ils conservent en faisant toujours porter sur la droite leurs mouvements principaux."[1] These arguments scarcely deserve serious consideration. Bichat seems to have forgotten that Eastern nations—the Jews, for instance—in writing move the hand from right to left, and yet are as much right-handed as ourselves. So also it is ludicrous to speak of the exigencies of neat military drill, or of æsthetic dislike to inharmonious dances, in the case of such races as the Andamanians, the Esquimaux, or the Fuegians. Yet all of these alike show dextral pre-eminence. Moreover, even allowing that convenience of any kind may have led the members of a savage community to select by consensus one side as that to be used preferentially in one-sided actions, we may still ask how came it that each savage race made the same choice? Why was the right side invariably selected by them all and in no single instance the left?

Bichat, indeed, seems himself to have felt the inadequacy of his explanation. For he allows that the selection may have been biassed in some very slight degree by certain peculiarities of our conformation. Digestion, he says, is attended by lassitude, which, owing to the position of the stomach, affects the left side more than the right, and leads us to give the former as much rest as possible. Of more importance is his statement that the right subclavian artery is slightly larger than the left one. If this be really so—

[1] 'La Vie et la Mort,' premiere partie. Art. prem., i.

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and Bichat's anatomical repute is, I suppose, a sufficient guarantee for the correctness of his statement—we can scarcely doubt but that the larger size of the artery is in some way or other connected with the pre-eminence of the right hand. It does not, however, by any means follow that it is the cause of that pre-eminence. It is equally possible that it may be its consequence, for increased use of an organ leads to increased size of its arteries. And that this is indeed the case is rendered the more probable by the fact that no similar difference of size has been noted in the arteries which go to the right and left legs, and yet dextral pre-eminence is not confined to the anterior limbs, but extends to the posterior ones, as, indeed, Bichat himself seems to allow. The difference between the two legs is not so striking, nor so easily observed, as that of the two arms; as is perfectly intelligible when we consider that no action of our ordinary life calls one leg by itself into play. I have, however, convinced myself by observations on boys playing at football, and learning to skate, that the right leg is used preferentially to the left by those who are right-handed, and *vice versâ* that the left leg is used preferentially by such as are left-handed. So also the right foot is, as a rule, somewhat larger than the left one. I am told by boot-makers that this is almost, though not quite, invariably the case, and such measurements as I have made confirm their statement. On the other hand, I found in two left-handed persons, whose feet I lately had the opportunity of measuring, that the usual proportions were inverted, the left foot being in both cases somewhat the larger, and in one of the two cases very considerably so.

Since the days of Bichat the question of right-handedness has ceased to attract much attention, and is scarcely, if at all, mentioned in our physiological text-books;[1] owing,

[1] Since the above was written a paper on "Left-handedness," by Dr. Pye Smith, has appeared in the 'Guy's Hosp. Reports.' After carefully reading that article I have not changed the opinions expressed in this communication; I have, therefore, thought it best to leave my paper unaltered, and refer my readers to Dr. Pye Smith's pages for the different views which he holds.

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apparently, to its being pretty generally admitted that the explanation of the matter is not to be sought in our bodily conformation, but in the effects of conventional education. This opinion I wish to combat, and I will now state in order the many objections which appear to me to render it untenable.

The first objection which I would urge is the one already mentioned. We can understand how possibly the individual members of a community might be led by convenience to agree to use one or the other hand and foot as the preferential organ, but there is no apparent reason why separate communities should all have come to the same conclusion, and should all have fixed on the right for the favoured side; and not some on the right, others on the left, as the law of chances would require.

Secondly, I would point out that the hypothesis which attributes dextral pre-eminence to mere education does not account for the numerous exceptions to the general law which notoriously occur. There are a vast number of individuals brought up under precisely the same conditions, as regards this matter, with their fellows, who yet are what is called left-handed, and who remain so in spite frequently of their eager wish to change their manner and accommodate themselves to the fashions of their companions. Such exceptions are much more numerous than is, I imagine, supposed. At any rate they are much more numerous than I myself imagined to be the case before I had taken the trouble of inquiring personally into the matter. Unable to find any reliable statistics, I went through the tedious task of asking 2000 consecutive hospital patients—1000 men and 1000 women—whether they were right- or left-handed. Of the 2000, no less than 85 were left-handed. There was a remarkable difference, as will be pointed out later on, between the 1000 men and the 1000 women; but at present I am only concerned with the general result, and that was that no less than $4\frac{1}{4}$ per cent. of this large number of persons were left-handed. If the education hypothesis were correct we shall expect to find that these 85 exceptionally

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left-handed persons were the children of left-handed parents, who had trained their offspring in their own peculiarity. But this was not the case. Of the whole 85 no more than 12 had a left-handed parent. I need hardly say that, as the statistics were obtained from hospital patients, the influence of nurses other than the parents may at once be dismissed as unimportant.

Any one, moreover, who takes the pains to inquire into the details of a few left-handed cases will soon find instances in which all idea of direct parental or educational influence will have to be abandoned. He will find cases in which a single member of a large family is left-handed, while the parents and all the rest of the children are right-handed. Thus (to give one instance out of many), I am acquainted with a gentleman, the fifth of a family of nine. He was brought up under the same conditions as his brothers and sisters. All these, as also his father and mother and his nurse, were right-handed. But he, in spite of all efforts to make him conform to the usual habit of the world, is so far left-handed still in adult life as to shoot from his left shoulder, hold the billiard cue in his left hand, and generally, with the exception of writing and holding his knife at dinner, to perform all acts requiring only one hand with the left.

A third argument is this. Left-handedness, though, as the remarks just made show, it cannot be attributed to the *direct* teaching of parents, is yet an hereditary affection; and the same phenomena are observable in its distribution in a family as are observable in the case of indisputably physical peculiarities, such as polydactylism and the like. Like them, it appears here and there in individual members of the family, so to speak, capriciously, that is without our being able to assign a definite cause for its presence or absence in the separate cases. Of this I have seen many instances, but I will only give one of the more striking ones.

C. S— is left-handed in a marked degree. She holds her knife at dinner, scrubs, washes, lifts heavy weights, with her left hand, invariably using, however, her right for the needle and for writing. Neither of her parents are left-handed; but

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her grandfather was. She has a sister who is left-handed; and this sister has a left-handed son and several other right-handed children. She has also four brothers, all right-handed; but one of these has a left-handed son, another a left-handed daughter.

I could multiply such examples. But any one who inquires into this matter will find they are of common occurrence. I will therefore content myself with giving the general result of my inquiries as to the hereditary nature of this affection.

Of fifty-seven left-handed persons of whom I made inquiries as to their relatives, no less than twenty-seven knew of one or more left-handed relatives within the degree of first cousin. Most of these fifty-seven persons were hospital patients, and these were rarely informed as to the whole number of their uncles, aunts, and cousins. Had they been able to give full information, doubtless the proportion of family cases would have been found to be larger. But even as it is, it would appear that in practically one half of the left-handed cases the affection was sporadic in the family.[1]

Left-handedness, then, resembles abnormalities of bodily structure in its "running in families." It resembles them also in another curious way, namely, in the different frequency with which it attaches to the two sexes. Of the 1000 men of whom I made inquiries, 57 were left-handed; of the 1000 women, only 28. In other words, this peculiarity is twice as common in men as in women.[2] Now, a precisely similar phenomenon is observable in the case of undoubted malformations. Most, though not all, of them are much more frequent in males than in females. Thus congenital talipes, according to Mr. Brodhurst, occurs

[1] In further confirmation of the hereditary nature of this affection, I may point out that all the left-handed persons mentioned in the Bible belonged to one single tribe, namely, the tribe of Benjamin. If we suppose that the patriarch Benjamin—"the son of my right hand"—was left-handed, the frequent occurrence of the like affection in his closely intermarrying descendants is only in accordance with what is noticed in other physical and therefore hereditary peculiarities.

[2] This accords with the somewhat exaggerated aphorism of Hippocrates—*γύνη δυδέμια ἀμφιδέξιος*.

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in three boys to one girl;[1] extroversion of the bladder, according to Geoffroy St. Hilaire, in eight boys to three girls.[2] Dr. Burt Wilder found polydactylism to be twice as frequent in men as in women.[3] Similarly, Mr. J. Wood, in speaking of the variations of the muscles in the human body, states that "the greatest number of abnormalities in each subject is found in the males;"[4] and Professor Macalister remarks to the same effect.[5] Inversion of the viscera, also, according to G. St. Hilaire, is more common in the male than in the female.

A fourth argument will come home to those who have had to do with left-handed children. The peculiarity manifests itself before education begins, and persists often with obstinacy in spite of all the efforts of the parent to overcome it. Every one who has paid attention to this subject must have seen or heard of cases in which this occurs. Not rarely even the child's left hand is confined so as to force it to use the right one. If the left-handed tendency be but slight, such

[1] 'Deformities of the human body,' p. 71. Mr. Brodhurst tells me that his statement was founded on a basis of 600 cases. Before I knew that he had examined into this point, I took the trouble of collecting cases from the records of St. George's, the Orthopædic, and the Children's Hospitals, and found that this deformity is much more frequent in males, though my figures do not give so great a difference as Mr. Brodhurst's. Of 565 cases which I gathered together, 326 were males, 239 females.

Of 149 cases of cleft palate which I collected, 82 were males, 67 females. But these figures are two small for any sure conclusion; and Mr. T. Smith, who has large experience in such cases, assures me that cleft palate is equally common in both sexes.

[2] 'Histoire d. Anomalies, &c.,' i, 386. The greater tendency of the male to vary than the female is the more curious, seeing that actual monstrosities are much more frequently female than male. Double monstrosities are, according to G. St. Hilaire, female in three cases out of four. Haller also says that there are many more female than male monstrosities. So also says Meckel ('Anat Gén.,' i, 86; 'Anat. Comp.,' i, 422 and 551; and 'Comm. de dupli Monstrosâ,' p. 14). "Lex est generalis, paucis tantum exceptionibus subjecta, monstra fœminina longe sæpius occurrere masculinis."

[3] 'Massachusett's Med. Soc.,' ii, No. 3, 1868, p. 9. Quoted by Mr. Darwin, 'Descent of Man,' i, 276.

[4] 'Proc. Royal Soc.,' xvi, July, 1868, pp. 519, 524. Also quoted by Mr. Darwin.

[5] 'Proc. Royal Irish Acad.,' x, 1868, p. 123. Also quoted by Mr. Darwin.

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measures often result in the child growing up to all appearances a right-handed being; but if, as also not rarely happens, the tendency be strong, the child will still in adult life retain some trace of its pre-educational preferences, and will use the left hand for purposes which have not been brought under control, such as throwing a stone and ball, or the like.

The fifth and last argument which I shall advance against the education hypothesis is this. Man is not the only right-handed animal, a similar peculiarity occurring in cases where education is completely out of the question. Thus, the observations which I have made on monkeys have convinced me that they, like men, are, as a general rule, right-handed. I have hunted in vain for any information on this point in works on natural history, and it may therefore be worth while to describe my observations. If, standing close to a monkey, one offers it a nut or apple, the monkey takes it with the nearest, and so the most convenient, hand, be this the right or the left, and will proceed to use both or either indifferently in conveying it to its mouth. But if, instead of standing close to the monkey's cage, one stands, bait in hand, at some distance—at such a distance that is, that right and left hand are equally distant from the tempting morsel—the monkey will stretch out one of its arms as far as possible through the bars of the cage; and in the great majority of cases the arm thus extended will be the right one. Some few monkeys, it is true, will stretch out the left limb; but this is comparatively exceptional, and, as I have said, in most cases it is the right arm which will be used preferentially. Moreover—and this is the most important point to notice—on repetition of the experiment it will be found that each monkey will act in precisely the same manner as it did on the first trial; that is, those which on the first trial extended the right will do the same on the second occasion, and similarly those that extended the left will again use the same arm. Now and then, doubtless, an exception will occur, just as a right-handed man may occasionally extend his left arm instead of his right to grasp an object. But the rule is

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as I have stated it. It requires some patience and some conscientiousness to make the experiments properly, but any one who will take the trouble to do so will, I feel assured, come to the same conclusion as that at which I have arrived. The year before last I spent much time in investigating this matter at the Zoological Gardens, and found that of twenty-three monkeys, twenty were right-handed, three only were left-handed. I learnt to distinguish the several individuals I observed from each other, and found that I could tell any companion who might be with me, with almost perfect certainty, whether a given monkey of the lot would protrude right or left, when tried in the way I have described. Now, it will hardly be asserted that a monkey is disciplined by its parents to use one hand in preference to the other; and the only conclusion one can draw is that the similar dextral pre-eminence of man and monkey depends on some common fact in their anatomical structure.[1]

There is another animal that, owing to the manner in which it uses its limbs, lends itself easily to experiment, namely, the parrot, and the large collection of these birds in the Zoological

[1] I have tried without much result to find out whether any similar difference between the two sides exists in the case of other mammalia. The restriction of their anterior limbs to progression leaves no other available method of examination than comparison of weights, and I have found it impossible to procure thoroughly reliable weight results from butchers and others. I am, however, informed by my butcher that he has weighed the two sides of oxen and of sheep as I requested, and that the right fore-quarter of an ox is, as a rule, some three or four pounds heavier than the left; the right fore-quarter of a sheep one pound or so heavier than the left. Other butchers, however, have told me that they find no such differences. As regards horses, Mr. Bicknell informs me that in two cart-horses killed for the horseflesh dinner at the Langham Hotel, the right fore-quarter in each case weighed exactly nine pounds more than the left. It will be noticed that these were cart-horses, not horses artificially trained to certain paces. These data are, however, too few to form the basis of any serious argument; and even should it turn out on further examination that in reality the right side of horses and of ruminants is somewhat heavier than the left, interesting in itself as the fact would be, it would still be open to question whether this difference in weight corresponded to a difference in functional activity. I have, therefore, determined to leave these animals aside for the present.

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Gardens affords an ample field for observation. If a parrot be made to climb up the wires of its cage and a nut be then put into its beak, the bird climbs back to its perch, and then, supporting itself on one leg, proceeds to manage its nut with the other. In the majority of cases the leg which is used preferentially as a support is the right one. There are doubtless exceptions in which the contrary is the case, but, as a general rule, it is the right which is selected. Moreover, on repetition of the experiment it will be found, as with monkeys and with men, that each individual parrot always acts in precisely the same way. Those which on the first trial support themselves on the right will invariably be found on a fresh trial to do the same, and the like uniform behaviour will be noticed in those that use the left. Of eighty-six parrots that I tested repeatedly in this way, sixty-three invariably supported themselves on the right leg, while the remaining twenty-three as invariably perched on the left one.[1]

I have, I should remark, seen it gravely stated that all birds necessarily support themselves on the right leg because the position of the liver throws the centre of gravity into the right half of the body. I cannot but think that in asserting this it has been forgotten that the difference in weight of the two sides in a bird thus produced is excessively small, and is, in fact, fully compensated, if not over compensated, by the stomach and, in females, the ovary being both on the opposite or left side of the body. Moreover, the fact, for which this inadequate explanation has been devised, is itself

[1] It may, perhaps, be objected that, as the parrot, though it perches on the right foot, uses the left to feed itself, it may as fairly be said to manifest a sinistral as a dextral pre-eminence. So far as my argument goes at present this is a matter of indifference. All that I have to insist upon is that the two sides are used differently. But, as a matter of fact, the pre-eminence must be considered dextral, not sinistral, for in the double act that part is fundamental which precedes the other. The parrot must rest itself upon the right leg *before* it proceeds to use the disengaged left; and so, also, the young parrot must first learn to support itself on the right before it can learn the after act of feeding itself with the free foot. In other words, the original selection is of the foot which shall serve as a support, not of the foot which shall be used for feeding, and this selection is in favour of the right as a rule.

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imaginary. Repeated observations of birds of various orders, other than the parrots, have led me to believe that not only is the left leg used as much as the right for perching, but that the very same individual uses sometimes one, sometimes the other, indifferently. Parrots are, in fact, the only birds in which I have been able to detect with actual certainty any pre-eminence in one side above the other.

The arguments I have now advanced are, I think, conclusive that the generally held opinion which attributes dextral pre-eminence to educational influence is erroneous. Still, I am far from supposing that the natural tendency may not be modified by education. I have already stated that I know of cases where a child that betrayed slight but indubitable tendencies to use the left hand preferentially has been brought by training to change altogether its habit, and has grown into an apparently normal right-handed man. When, however, the left-handed tendency is more strongly pronounced, the effect of education extends only to such actions as are directly subjected to control by the parent. What the child is taught to do constantly with the right hand it learns to do with that member, but such actions as are abandoned to its own will continue to be executed with the left. Rarely, for instance, if ever, does a child learn of itself to write. This is always a matter of teaching; and thus, however strongly left-handed an adult may be, he is always found to use the right hand for this office. Out of more than 100 left-handed persons whom I have observed, only four professed that they could write with the left hand. One of these was paralysed on the left side, so that I could not compare the writing of the two hands, but he wrote well and currently with the right hand. In two of the remaining three the handwriting executed with the left was clumsy, and done slowly and with difficulty, while that executed with the right was easy and in every way superior. The fourth case was the only one in which the left hand seemed equally good with the right. But this was the case of a child, as yet only half taught, and whose writing was unformed and rudimentary.

So also with the manual operations of skilled mechanics.

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These are, like writing, matters of education and discipline, and are rarely found to be performed even by left-handed men excepting with the right hand. Untaught operations, on the other hand, such as the unskilled labour of mechanics, the lifting and carrying of weights, the wringing of linen, the manual part of games, such as ball-throwing and the like, continue, as a rule, to be performed by such men, even in adult life, with the left. Even these untaught actions, however, are sometimes gradually modified by the efforts of the child to imitate its playfellows and avoid their ridicule. This feeling of shame, so to speak, is of course much stronger in the well-nurtured than in the uneducated; and thus it is that I would account for the fact that left-handedness is apparently much less common in the upper and middle classes than in the lower. One can hardly look at a village cricket-match without seeing one or more left-handed players, while among gentlemen such is quite exceptional.

The very different degrees in which a left-handed tendency manifests itself in young children seems to me to be best explained by supposing that the great majority of men have a natural bias to use the right side in preference to the left; secondly, that there is a small minority who have an equally decided tendency to use the left; while, thirdly, there is another class without any natural bias at all. These latter are easily taught to follow the ordinary fashion, and in adult life will not be distinguishable from purely right-handed men. In a certain sense these may be called ambidextrous, though they may also equally well be called ambisinistrous. For their ambidexterity does not consist, as is usually implied by the term, in their having two skilful hands, each equivalent in value to a right one, but in their having two hands neither of which possesses the normal superiority of the right, and neither the normal inferiority of the left.

Right-handedness, then, though to a certain extent it may be strengthened or modified by education, has some or other basis in our bodily conformation. The next question to be considered is what this basis may be.

It is now a fact established beyond all dispute, in spite of the

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opposition with which it has met, that the views originally propounded by M. Dax are correct, and that the mental faculties concerned in speech are, in the great majority of men, lodged in the left cerebral hemisphere. It is, however, unquestionable that now and then an exception to this rule occurs. In a paper published in 1867[1] I suggested that it might possibly be that these exceptions were cases of left-handed persons in whom the cerebral hemispheres were, so to speak, transposed. If this were so, it will, I think, be admitted that we should have clear proof that the normal pre-eminence of the right side of the body is due to a normal pre-eminence of the left hemisphere, and the exceptional pre-eminence of the left side to an exceptional pre-eminence of the right hemisphere. Since that paper was written I have seen near upon a hundred cases of paralysis with more or less impairment of speech, and I have taken pains in each case to ascertain whether the patient was right- or left-handed. In all but three instances the patient was right-handed, and in all this large majority the palsy was on the right side. In the three exceptions the palsy was on the left, and each of these three persons was left-handed. A case has also been published by Dr. Jackson of aphasia with left hemiplegia, which was at first supposed to be an exception to Dax's law. But in this case also it turned out, on Dr. Jackson making farther inquiries, that the patient was left-handed.[2]

There can then, I think, remain no fair doubt but that right-handedness depends on some predominance of the left brain, and left-handedness, when it occurs, on a transposition of this structural peculiarity, whatever it may be.

It may, perhaps, be urged that there are recorded cases in which the aphasia coincided with left hemiplegia, and yet the patient was not reported to be left-handed. But in answer to this I would say that none such have been recorded since special attention was directed to the probability of right- or left-handedness being concerned in the matter, and that without special inquiry it is very easy, as Dr. Jackson's case

[1] 'St. George's Hosp. Reports,' vol. ii, p. 122, 1867.

[2] 'Lancet,' 1868.

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shows, for the coexistence of left-handedness to escape notice. Even should such a case occur it would not be necessarily incompatible with the views now expressed. For, as I have already stated, there are probably persons with a natural left-handed tendency, in whom the bias is so feeble that its external manifestations become completely masked by education. In such a person aphasia might occur with left hemiplegia, and such a case would then appear erroneously to stand in contradiction with Dax's law.

Opposed as this view of a structural and functional distinction between the two hemispheres is to our previous notions, it is not without strong support from other facts. Thus, Mr. Callender has shown, in an interesting paper recently read before this Society, that, while convulsions are a common accompaniment of disease of the right hemisphere, occurring in 39 out of 61 cases, they are but rarely produced by disease of the left hemisphere, having been present in only 7 cases out of 48. Dr. Boyd, again, found, by examination of nearly 200 brains, that "almost invariably the weight of the left hemisphere exceeded that of the right by at least an eighth of an ounce."[1] Lastly, Dr. Brown-Séquard, in a paper which I have not yet had an opportunity of reading, has stated his belief that the right side of the brain is more especially concerned with the organic functions, while the left more directly governs those of animal life.[2]

Having now traced back dextral pre-eminence to some or other difference between the left and right sides of the brain, we have next to inquire in what this difference consists.

In the paper to which I have already referred I pointed

[1] 'Phil. Trans.,' 1861, p. 261.

[2] To the differences above enumerated must be added that noted by Dr. Bastian; who found ('Journal of Mental Science,' xi, 492) that the average specific gravity of the gray matter of the left hemisphere is higher than that of the right.

"Budge, Valentin, et Schiff affirment qu'on peut exciter les contractions de l'intestin et de l'estomac à l'aide de stimulation directe des couches optiques, et Budge pretend que ces effets se produisent surtout quand on agit sur la couche optique droite."—Longet, iii, 415.

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out that the convolutions on the two sides were far from symmetrical, and that though this asymmetry was apparent in some inferior animals, it was most conspicuous in man, and I suggested that this anatomical difference, in all probability, corresponded to some difference of function, qualitative or quantitative. At that time I knew of no law discernible in this asymmetry. I have since learned from Dr. Broadbent,[1] and have verified the fact by numerous examinations, that, as a general rule, with very few exceptions, the frontal convolutions are much more complicated upon the left side than upon the right. It is hardly necessary to point out that greater complexity of convolution means greater development of gray matter, and is an unmistakable token of superiority. The left hemisphere, then, is not only heavier than its fellow, but more highly developed, and it is in this structural peculiarity that I find the explanation of dextral pre-eminence.

It is, however, manifest that if this be so the structural peculiarities ought to be reversed in the brains of left-handed persons. After long waiting I succeeded in obtaining the brains of two left-handed women; and anxious that they should be examined, not only by a most competent authority, but by one who was free from any preconceived ideas which might prejudice his judgment, I got Dr. Broadbent to be good enough to investigate them. He has kindly favoured me with a most minute and careful account of each separate fissure and convolution, and with drawings which are exhibited, as also the brains themselves, to the Society. For my present purpose it will suffice to say that, as I had anticipated, the ordinary conditions of the two hemispheres

[1] From the following passage in an article on "Aphasia," by Dr. Bateman ('Journal of Mental Science,' October, 1869), I learn that M. Broca has also noticed the same fact as Dr. Broadbent. "M. Broca, who never takes anything for granted, and whose indefatigable zeal led him to examine forty brains, came to the conclusion that the convolutions are notably more numerous (?) in the left frontal lobe than in the right, and that the converse condition exists in the occipital lobes where the right is richer in convolutions than the left."

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were in each of these brains reversed, the greater complexity of convolution occurring in both on the right side and not on the left.

In one of the two brains the difference of the two sides was very conspicuous, and the greater complexity included all the convolutions on the right outer surface alike. In the other the greater complexity of the right hemisphere was apparently limited to the frontal and parietal convolutions, the occipital lobe being more complicated on the left. This is, indeed, a more perfect inversion of the two sides than in the other case, for, in the ordinary normal brain, while the frontal convolutions are more complex upon the left, the occipital convolutions are, on the contrary, more complex upon the right.

There remains, then, no possible doubt but that right-handedness and left-handedness are associated respectively, the one with a more highly developed left hemisphere, the other with a more highly developed right one.[1] It may, however, be objected that this association admits of another interpretation than that which I have put upon it. That the greater development of the left brain may be the consequence of the increased use of the right side, and not its cause. A perfectly conclusive answer to this can only be obtained by an examination of numerous fœtal or infantile brains, and of this I have had no opportunity. I would, however, urge in answer the observation of Gratiolet, disputed though its correctness has since been, namely, that the convolutions of the left frontal lobe appear earlier in the fœtus than the corresponding convolutions of the right. Seeing, however, that we know, if the arguments I have used in the earlier part of this paper be valid, that some or other anatomical difference between the two sides *must* precede the right-handedness, and, moreover, that this difference *must* be somewhere in the brain (for how otherwise can the facts I have brought forward concerning aphasia be explained?) it appears to me only rational to suppose, when one finds such

[1] Or, more accurately, with more highly developed frontal convolutions, in the one case on the left, in the other on the right.

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an anatomical difference between the two hemispheres as that now revealed, that this anatomical difference is the antecedent for which one was searching. The objection appears, then, to me to be at least hypercritical. Still, it will be well for those who may have the opportunity still further to examine into the correctness or error of Gratiolet's disputed statement.

So far, then, we have advanced with what I venture to think are pretty sure steps. There still remains, however, a further question on which I would express myself with some hesitation. To what are we to attribute this greater and, if Gratiolet be right, this earlier development of the left hemisphere? In the paper to which I have already twice referred, I expressed an opinion that the cause was to be found in the difference of the blood supply to the two sides of the brain; and to that opinion, though with some reserve, I am still disposed to adhere. In the first place, I find that the arteries which convey blood to the brain are, as a rule, somewhat larger on the left side than on the right, and that this rule apparently breaks down in the case of left-handed men. In twelve out of seventeen cases of right-handed men, in whom I examined the cervical vessels, either the common or the internal carotid was larger on the left side than on the right.[1] In the remaining five cases no difference could be detected. It is so rarely that one is able to get a post-mortem examination of a person known during life to have been left-handed, that I can give only very insufficient facts as to the conditions of the vessels in such cases. In three such instances, however, I have had the opportunity of examining the cervical arteries. In none of these three was the left carotid larger than the right, as in the great majority of right-handed men. In two of the three there was no apparent difference, while in the third

[1] The difference of size between the right and left carotids is very small. But a very small difference in calibre means a very considerable difference in result. For Poisseuille found that the amount of fluid discharged by small tubes increases, *cæteris paribus*, in proportion to the diameters of these tubes raised to the fourth power.

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case not only were the right common and internal carotids nearly twice the size of the corresponding vessels on the left, but a similar disproportion, also in favour of the right, existed between the middle cerebral vessels. This is the only case, either of right- or left-handed subjects, in which I have found any difference of size between the two middle cerebral arteries.

It would appear then that, as a rule, in right-handed men the left carotid artery is larger than its fellow; and such scanty facts as can be given favours the idea that in left-handed men this condition is reversed. But here the objection, so often already alluded to, may be advanced with great force—that the increased size of the artery is the consequence of the increased use of the hemisphere to which it goes, and not its antecedent. While I fully admit the possibility and even the probability of this, I would urge one small fact which tells in the contrary sense, and seems to point to there being some tendency in the left arteries which go to the head to be larger than the right ones, quite independently of any difference in the functional activity of the parts which they supply. That small fact is this. The two vertebral arteries, which unite to form the basilar before they reach the brain, and which must, therefore, be precisely alike so far as the *vis a fronte* goes, yet often differ in size. And when this is the case the left is found to be the larger one more than three times as often as the right. In twenty-six cases Dr. Davy found the left the larger, while in only eight cases was the advantage on the side of the right.[1]

Still, it must be admitted that the somewhat larger size of the left carotid is of dubious interpretation. There is, however, another advantage enjoyed by the left half of the brain which is not open to the same doubt. The amount of blood received by the two hemispheres respectively will depend, not merely on the relative size of the carotids, but also, *cæteris paribus*, on the relative tortuosity of these vessels. Every curve or angle in an artery, and every division in its course, is an obstacle to the flow of blood

[1] Cf. 'Edin. Med. Journ.,' li, p. 70.

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through it, and will retard the current; and the sharper the angle is the greater will be its retarding effect. Thus, if two tubes of equal lengths and diameters, but one bent, the other straight, be run through the side of a barrel of water, it will be found that more fluid will be discharged in an equal time by the straight tube than by the bent one. Now, as the right carotid is given off from the innominate, while the left carotid is given off directly from the aorta itself, it is plain that the blood which reaches the former has one extra angle in its way. Moreover, it will be seen, on examining the larger vessels *in situ*, that while the left carotid, as a rule, is given off from the arch at such a point and in such a direction that its axis lies in the same line as the blood-current of the arch, so that the blood will pass into it directly without making any angle at all, the innominate is given off at a very considerable angle to the blood-current, so that the blood which reaches the right carotid has in reality to get round two retarding angles, first into the innominate, and then from this into the carotid; while the blood which passes into the left carotid has neither of these hindrances. The left side of the head will thus, as a rule, receive a more abundant flow of blood than will the right; and to this it is that I would attribute the greater development of the left hemisphere. I need hardly say that even within the limits of what is called the normal condition of the arch and its branches there are numerous small differences, and that the exact angles and positions at which the several branches are given off differ somewhat in different cases. With these variations will vary the degree of advantage enjoyed by the left side, and thus it is that we can account for the different intensity of the right-handed bias in different individuals. We can also readily understand how the angles of division may not unfrequently be such as to give no advantage whatsoever, in which case the person will be without any natural one-sided bias, though in all probability he will by education assume a right-handed habit. Neither is it difficult to understand how occasionally, be it by alteration of the angles and positions of the large

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vessels or by counteracting differences in their later subdivisions, the advantage may even be on the side of the right, in which case the person will have a natural left-handed bias, even though the arterial branching be not what would ordinarily be considered abnormal.

It will naturally be objected that, if this explanation were true, we ought to find left-handedness the rule in such persons as have their viscera transposed. It must, however, be remembered that we must not expect to find all such persons left-handed. For the inverted arch will be subject to variations in the angles and positions of its branches, just as is the normal arch, and these variations will have analogous effects. So also we must remember that the apparent exceptions will be much more numerous in the persons with inverted arch than in the persons with normal arch. That is to say, very many more of the former must be expected to be right-handed than are found to be left-handed among the latter. For in both classes alike those individuals whose two hemispheres receive equal amounts of blood will, from the action of education on their naturally indifferent condition, become by habit right-handed, and such will be apparent exceptions in the class with inverted arch, but not so in the class whose arch is normal. All, in fact, that we can properly expect to find is, that a larger proportion of persons with inverted viscera is left-handed than of the world at large. Now, is this really the fact? I believe that it is. But the data are so few and vague that it is impossible to give a certain answer, and it is the want of better evidence on this point that makes me hesitate as to the validity of the explanation I am offering. There are but few cases of transposed viscera recorded, and in still fewer is it also recorded whether the subject was right-handed or not. Out of the very small number, however, in which this point has been attended to, a much larger proportion seems to have been left-handed than accords with the general average, which, as we have seen, is about 4¼ per cent.[1]

[1] The fact that left-handedness is much less common in women than in men, and the observation of G. St. Hilaire that inversion of viscera is also more common in males than in females, taken together, are in complete harmony with the views expressed in the text.

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So many cases, indeed, of inverted viscera with left-handedness have apparently been noticed, that Professor Hyrtl and others have thought that a constant coincidence existed between the two conditions. This, however, is certainly not the case; nor, indeed, should it be expected to be the case if the hypothesis I am advocating be true. As to those cases in which the viscera were transposed, and yet the persons were apparently right-handed, it must also be borne in mind that slight degrees of left-handed bias, as I have already noticed, frequently give way to the force of education, and this may very probably have happened in some of these.

Lastly, it may be asked, will the explanation here given embrace the cases of monkeys and of parrots, animals which, as we have seen, also manifest dextral pre-eminence, and does their left brain enjoy any vascular advantages over the right? It will, I think, be admitted that, if this could be shown to be the case, it would afford a very strong argument in favour of my explanation. As regards monkeys, I can but say that their hemispheres are known to be highly unsymmetrical, and that their arterial branchings appear to accord generally with those of man. But in parrots I find a striking corroboration of my hypothesis. In these birds there is a very great variability in the arrangement of the right and left carotid arteries. In some few the two are of equal size. But this is the exception. In the great majority the arteries are unequal, and when this is the case it is invariably the left carotid which is the larger of the two, as Meckel[1] years ago pointed out. Sometimes, indeed, it would appear that the right carotid is rudimentary, or even entirely absent, and that the brain receives its whole blood supply from the vessel on the left. It is difficult to suppose that this is a mere coincidence; but if it be anything more, it renders the explanation I have advanced in the highest degree probable.

In conclusion I must thank the Society for listening to a lengthy paper on what may seem to many a small and un-

[1] 'Anat. Comparée,' ix, 366.

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important question. The problem, however, is one which has occupied men at intervals for more than 2000 years, and would on this ground, if on no other, merit some attention. But besides this, it is not without more important bearings. The question whether the two sides of the brain are to be looked on as simple repetitions of each other, as most of us have been taught, or whether they are not in many points functionally dissimilar, as many are beginning to suspect, is one in which physiologists and pathologists alike are deeply concerned, and the close connection of the point we have been discussing with this important question is sufficiently apparent.

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