

Can the existence of a tendency to change in the form of the skeleton of the parent result in the actuality of that change in the offspring? / by W. Arbuthnot Lane.

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Lane, William Arbuthnot, 1856-1943.
Royal College of Surgeons of England

Publication/Creation

[London] : [publisher not identified], [1888]

Persistent URL

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Change in the Form of the Skeleton

by

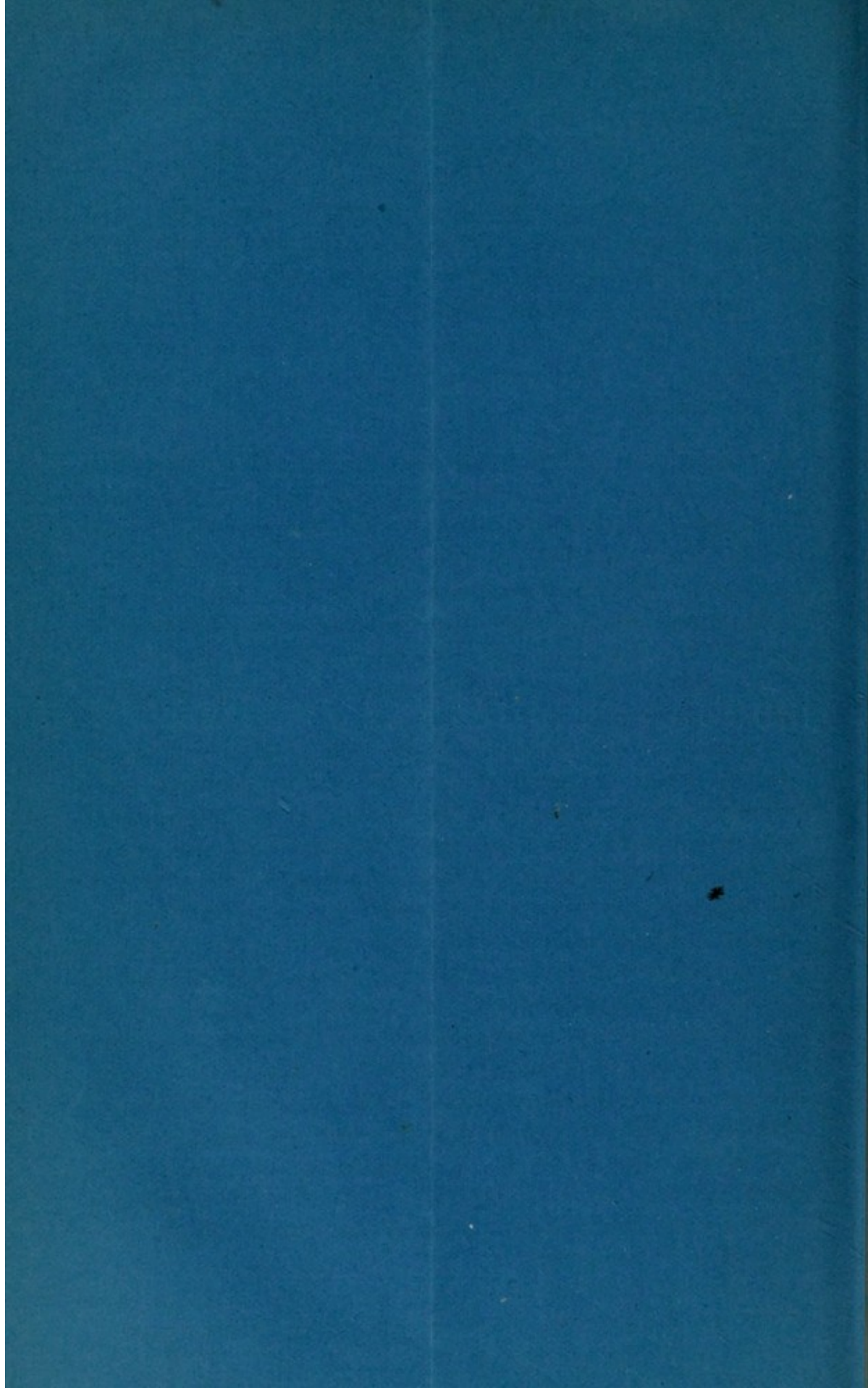
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FROM THE

JOURNAL OF ANATOMY & PHYSIOLOGY

1888 VOL XXII.





JAN 13 1892
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CAN THE EXISTENCE OF A TENDENCY TO CHANGE
IN THE FORM OF THE SKELETON OF THE
PARENT RESULT IN THE ACTUALITY OF THAT
CHANGE IN THE OFFSPRING? By W. ARBUTHNOT
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IN a paper read recently before the Fellows of the Obstetrical Society, entitled "What are the Chief Factors that determine the Differences which exist in the form of the Male and Female Pelvis?" I attempted to prove the two following hypotheses:—

Firstly, "That the development of arthrodial joints in the pubic symphysis and sacro-iliac synchondrosis of the female during the later months of pregnancy is a mechanical result of the presence of a heavy bulky mass in front of the spinal column during that period."

I supported this statement by the description of analogous changes which are produced in workmen by carrying loads whose position bears the same relationship to the lumbo-sacral articulation as does the foetus in the pregnant female, and of the mechanical means by which these amphiarthrodial joints are raised to a higher stage of development during a portion of the lifetime of the individual. This theory received the assent of a very eminent authority on the mechanics of the female pelvis.

The *Second* hypothesis was of a more complex character. It was "*that a force which produces no obvious change in the skeleton of the antecedents, but only a tendency to change, can, acting as a developmental factor, cause the apparently spontaneous development of that change in the offspring.*"

I applied this theory to the skeleton of the trunk of the human female, and I attempted to show that the differences which existed between this portion of the skeleton in the two sexes were instances of it.

I will state them briefly.

(1) The presence of the foetus during the later months of

pregnancy, acting in the same manner as a dead weight occupying the same relative position to the column, *tends* to produce in the fully developed skeleton changes similar in character to those which are developed during the lifetime of an individual by the habitual action of a heavier load similarly supported, and that though this tendency to change may produce little or no change in the individual, it may determine the apparently spontaneous development of the change in the offspring.

The characters here referred to are the lesser depth of the sacro-iliac synchondrosis and of the pubic symphysis in the female subject, the lesser depth of the true pelvis, the difference in the shape of the sacrum, the slighter prominence of the lumbo-sacral angle, the altered direction of the plane of the facet on the upper surface of the sacrum, and of the superior articular processes, the different shape and development of the spinous process of the sacrum, the increased diameter of the conjugate of the outlet, and the variation in the greater extent of the sacro-sciatic ligaments.

(2) The foetus, existing as a bulky mass during the later months of pregnancy, presses upon the lower portion of the thorax, distending it and diminishing its respiratory capacity. It consequently *tends* to produce an increased development of the respiratory capacity of the upper portion of the chest, as indicated by an increase in the spans of the upper ribs, in the breadth of the upper interspaces, and in the depth of the manubrium; to increase the interval between the symphysis pubis and the sternum, and consequently to diminish the length of the gladiolus; also to render the manubrio-gladiolar articulation very freely movable. The pressure exerted by the foetus as it encroaches upon the fully developed thorax must tend to produce the above changes in it, and it is, therefore, quite apparent that these changes which are present in the female pelvis are the expression of the progressive or evolutionary tendencies in the antecedents as progressive actualities in the offspring.

(3) Again, in the same manner, the pressure which the bulky foetus exerts upon the iliac bones *tends* to produce their expansion and flattening, with separation of their anterior superior spinous processes.

(4) Lastly, the foetus, as it passes through the true pelvis, *tends* to increase its calibre and the size of the angle between the pubic and ischial rami, and to evert and render smooth the edges of these bones; also to separate the ischial tuberosities, and to alter the direction of the spinous processes of those bones.

If the above assumptions are true, it is obvious that the variations which exist between the forms of the pelvis in the two sexes, as well as of the rest of the skeleton of the trunk, are due to the weight of, and the pressure exerted by, the foetus in the later months of pregnancy acting as an evolutionary tendency to change.

The difference in the forms exhibited by the pelvis and thorax in the several sections of the quadrumana can, in view of the knowledge which we possess of the changes produced in the human subjects by the carrying habitually of very heavy loads, be easily explained by a consideration of the attitudes habitually assumed by each group of animals. The same line of argument may be applied to the influence of the weight and pressure exerted by the foetus in the quadrumana.

It must be quite apparent, in the transition from one type to another, that while the gradually and newly acquired habits of the parents *tend* to but do not actually produce in them an alteration in their anatomy, yet the tendency evolves the factor which *produces* in the offspring the actuality of the change.

I would point in support of this hypothesis to the gradual appearance of asymmetry of the costal cartilages and of the pleurostea of the sternum in the higher apes, and to its gradual disappearance in man. In a previous contribution to the *Journal of Anatomy and Physiology*,¹ "The Causation of several Variations and Congenital Abnormalities in the Human Subject," p. 594, I explained the manner in which this asymmetry was produced, and I showed that it was due to gradual change in the habits of the various groups of animals.

It must be quite apparent that in this instance the factors which, acting as a hereditary tendency to a change, brought about that change in the offspring, could not have produced its actuality in the parents during their lifetime.

The variations in the form of the skeleton of the trunk, and

¹ Vol. xxi., New Series vol. i. p. 586.

in the formation and detail of its component parts, afford another very strong argument in favour of this hypothesis.

We have only to compare this portion of the body in the several sections of the quadrumana and in man, and to observe the form of the thorax, the number of vertebræ above the sacrum, and the shape of the pelvis in the lower orders, and the alterations which these portions of the skeleton develop in the anthropoid apes, in accordance with the habitual assumption of acquired habits; and, again, the changes they undergo in man in consequence of the same cause, to become firmly convinced that the factors that determine these changes are purely and simply mechanical, and that they act as evolutionary tendencies to change, and not necessarily by the production of an actuality of the change in the parent.

I do not for one moment intend to suggest that, apart from the changes which I have shown to develop in joints and in the ends of the bones entering into their formation during the lifetime of an individual, in consequence of the habitual performance of a single function, there is no other actual change in the skeleton. On the contrary, I have found that bones will undergo remarkable changes in form during the lifetime of a single individual, owing to the habitual presence of a tendency to the development of one portion or portions of the bone rather than others, resulting from the habitual performance of certain definite movements. I do not refer merely to such obvious results of occupation as an excessive growth of the lesser trochanter of the femur, but rather to alterations in the form of such a bone as the scapula, and in the extent of development of its component parts. These alterations are not so readily noticed, and in the same proportion their causation is more obscure.

Broca, Flower, Sir William Turner, and other observers have called attention to the variations which the scapula presents in different races. Professor Turner concludes that to some extent the habits of a race will affect the configuration of the skeleton. In his paper "On Variability in Human Structure,"¹ the reader will find the subject fully discussed. I have found in the dissecting-room spines presenting quite as marked diminution in the convexity, or showing as distinct concavity, of the lumbar

¹ This *Journal*, vol. xxi. p. 473; also "*Challenger*" *Reports*, part xlvii., "Human Skeletons."

spine as did those of the Australians, &c., which he describes. Is it possible that the habit of wearing heels is responsible for the greater convexity of the lumbar spine in Europeans? I hope in a subsequent paper to show that similar variations in the form of the scapula and of other bones exist in the inhabitants of our island, that peculiar variations belong to certain occupations which are commenced at an early period of life, and are carried on up to the end, as, for instance, that of shoemaking, and I also hope to be able to demonstrate with some accuracy the special group of habitual movements which determines each variation. Personally I am convinced of the accuracy of this statement, though it is obvious that it will require much time and trouble to obtain sufficient material to render it as complete as one would wish for purposes of demonstration.

There is also to be observed in man a still further degree of development, which I believe to be due to the acquired habit of wearing boots with heels, by means of which the direction of transmission of superjacent weight through the lumbo-sacral articulation is altered. I allude to the existence of an additional vertebra above the sacrum, due to a separation of its first piece. Associated with this dissociation of the first sacral vertebra there is an altered type of pelvis, a change in the form of the thorax and of the lumbar spine, &c. Observing these changes, it is again quite apparent that the acquisition of the habit could not have produced them in the parent, but that instead they produced in him a tendency to change, which resulted in the actuality of the change in the offspring.

Though, as has been frequently asserted, we do not get individuals who are definite examples of transitional types, yet we are able to recognise and observe in each group individuals possessing some of the characters which are regarded as characteristic of another group, and which show that a change in form is still going on in one apparently distinct group of individuals, and that this change can be distinctly observed and measured.

I will take man, as I know more about the variations in his anatomy than in that of other animals.

Among the bodies that come into our possession for the purpose of dissection, we observe that the majority of individuals possesses a certain average type of skeleton, which we are

accustomed to describe as normal, and that there is a small proportion which possesses characters which are distinctive of the higher apes, and are not sufficiently recognised in their entirety. These characters we speak of as simian. The one usually recognised is the union of the fifth lumbar vertebra with the sacrum to form its first piece, and the diminution of the number of vertebræ above the sacrum by one; and another very obvious one is the asymmetry of the costal cartilages and sternal pleurostea to which I have called attention. There are associated with this fusion of the fifth lumbar vertebra with the sacrum very definite and obvious deviations from the so-called normal type in the whole of the skeleton of the trunk, all of which correspond in character more or less to those in the higher apes. There are, I believe, associated also with these variations in the trunk very definite changes in the remainder of the skeleton; but though I have obtained some apparent proof of this, I am not prepared to formulate them very definitely just at present.

Now, between the distinctly simian type of skeleton and the so-called normal skeleton, we get in man every degree of variation.

Again, in man we have, as I have already stated, a fairly large proportion of individuals of the male sex whose skeletons present variations from the normal, the most obvious of which is the separation of the first piece of the sacrum to form an additional vertebra above that bone.

As in the case of the simian type, so in this, I have found that there is associated with this separation of the first sacral vertebra a very distinct group of variations in the skeleton of the trunk, and I believe also in that of the whole of the body. There is between the normal type and the fully developed variation just described every intermediate degree of development.

I have observed that the human female pelvis, as seen in our dissecting-rooms, does not display either of the conditions I have described as dissociation of the first sacral vertebra or that of fusion of the fifth lumbar and first sacral vertebræ. It is therefore obvious, that while the female skeleton assumes more rapidly than does the male the form that may be regarded as

its normal type of pelvis, yet it resists in a remarkable manner the tendencies which succeed in producing change in the male, though it appears almost absolutely certain that it is subject to their influence. It is also apparent that the early assumption of the normal type by this portion of the female skeleton, and the resistance to change which it displays, are the products of the evolutionary or developmental tendency produced by the mechanical influence exerted by the foetus. Though the female pelvis does not undergo any apparent alteration in consequence of the influence of the mechanical factors which determine the change in the male, yet it may reasonably be supposed that the same factor produces a greater compensatory change in the remainder of the body than it does in the male.

I believe that exactly the same variations in two directions can be readily demonstrated in any race of the higher apes, and I think therefore that we may assume the same holds good for animals lower in the series.

It seems to me that we are wrong in looking for what is commonly called a transitional type, in the sense of an animal possessing characters exactly intermediate between one group and another,—for instance, between the supposed typical anatomy of man and of the higher ape.

If the hypothesis that I have laid down as to the transmission of a tendency being followed by its actuality, and that this tendency is always mechanical in character, be true, it is apparent that the acquisition of certain habits may cause one portion of the anatomy to vary in one direction and another portion in another.

This would account for the fact that we are unable to show absolutely that one race approaches more nearly to the higher apes in *all* its characters than another.

I was much struck by this in reading papers which interested me deeply in the *Journal of Anatomy and Physiology*.¹ It is obvious that in order to produce a type possessing characters intermediate between those of the higher ape and

¹ "On Variability in Human Structure as displayed in different Races of Men, with especial reference to the Skeleton," by Sir W. Turner, vol. xxi., N. S. vol. i., also "The Sacral Index," Jan. 1886; "The Lumbar Curve of the Spinal Column in Several Races of Men," April 1886, vol. xx., &c.

of man it would be necessary that successive groups of individuals forming that highest order of apes be exposed continually to exactly the same variations of climate and surroundings, be made to follow exactly the same variations of pursuits, occupations, and habits, and to procure the same changes of food. By this means the anatomy of the race would be subjected to exactly the same mechanical forces, and identical tendencies resulting in identical actualities would result.

It is the reversing of this uniformity that has resulted in the present condition of the human race and in the absence of an intermediate type.

In a typical case of dissociated first sacral vertebra do we also find that the shape of the skull varies from what is regarded as the normal type, in a manner similar to that in which the component parts of the trunk do in response to the alteration in their mechanical surroundings, whether it be produced, as I believe it usually to be, by an alteration in the normal antero-posterior plane of the foot by wearing heels, or by any other cause which in a similar way modifies the manner in which superjacent weight is transmitted through the lumbo-sacral articulation?

I am rapidly collecting material by means of which I think that I shall be able to prove this, namely, *that the form of the head, like that of the components of the trunk, and probably also of the limbs, will undergo a change in response to a variation in its mechanical relations to its surroundings.*

Another question arises if we assume that my hypothesis is true, which I believe it is, namely, Are the contents of the cranial cavity altered in their detail by the change in the form of the cranial cavity, or is the same brain merely packed in a different manner?

Putting this question differently,—Is it possible to alter the detail of the brain by developing mechanical tendencies to growth in certain directions?

I wont attempt to answer this question now, but will pursue the investigation in another direction.

In analysing the causation of the variations that exist between the form of the skull in the higher apes and in man, the explanation of the changes in form is more complex than it

is in the case of the associated variations in the form of the several component portions of the trunk.

This is owing to the fact that in the cavities of the trunk the contents undergo no practical variation, but in the case of the skull, besides the presence of the mechanical factors which develop tendencies to change in consequence of the habitual assumption of the more or less erect attitude, there are associated progressive alterations in the arrangement and size of the cranium and of the cranial contents.

Another difficulty now arises in understanding how far the alteration in the form of the skull, which was consequent upon a change in the habits, surroundings, and necessities of the individual, was the direct mechanical cause of the assumption of the erect posture, and how far the alteration in form resulted from a mechanical tendency to the enlargement of the portion of the head above and behind the occipito-atloid articulation, as the result of a prolonged life and increasing experiences.

What I mean is that the alteration in the character of the food, surroundings, and necessities of the individual would exert a tendency to the diminished development of the prominent powerful jaws and the large projecting snout with its extensive mucous membrane.

Associated with this there would exist a tendency to the diminution of the large olfactory and other sensory centres which are placed anteriorly in the brain. As these tendencies become actualities in the offspring, it is quite intelligible that in consequence of these changes the animal will assume and retain the erect position with greater ease than did the parent.

The increasing length of life of the individual, and its associated increasing and varied experience, would tend to the increased development of that portion of the brain which is situated above and behind the occipito-atloid articulation.

It is possible, also, that the mere habitual assumption of the erect posture may of itself tend mechanically to the diminished development of the projecting jaws and snout, to a diminution in the development of the sense of smell, and to a consequent and necessary increase in the development of other portions of the brain.

It is, I think, apparent that changes take place in two

directions, and that in either case the manner in which they are produced is purely mechanical.

I might remind the reader that in a preceding paper I showed from the measurement of many human skulls that a considerable and variable asymmetry of this portion of the skeleton was very frequently present. In a very large proportion the left side of the skull was larger than the right, and in a small minority the left half was smaller than the right. I ascribed this to the increased experience which the right side of the body has acquired as compared to the left. In cases of apparently considerable asymmetry, it seemed to me that the skull was balanced by being placed somewhat obliquely upon the articular surfaces of the atlas.

We have only got to determine more accurately the manner in which the several component parts of the body respond mechanically to changing surroundings, and we will be able to explain not only the variations which exist between the forms of the skulls and other portions of the skeleton of different human races, but also the transition of the simian to the human type.