I may add that a tube draining away from the axilla was kept in for three days, and after its removal, union of the incision, about four inches long, was complete when the sutures were removed. The patient returned to Wales a few days after operation. I have arranged for a report as to any recurrence hereafter, but venture upon a favourable prognosis.

(To be continued.)

THE RESULT PRODUCED UPON THE MUSCLES, BONES, AND LIGAMENTS BY THE HABITUAL EXERCISE OF EXCESSIVE STRAIN.¹

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We may, I think, consider that the normal anatomy of the human skeleton has been developed to perform two distinct sets of functions, namely, to transmit weight and to sustain strain in the varying attitudes of the individual; or, in other words, that the form of the skeleton has been evolved in consequence of the habitual mechanical relationships which have existed and do exist between the organism and its surroundings. Since this relationship has not been constant in the same portion of the globe at different periods of time, nor is it constant in different portions of the globe at the same period of time, we get a considerable variation in what may be regarded as the typical anatomy of each of the several races which are scattered over the earth's surface.

Again, the reproductive function of the female entails the presence of a bulky mass which occupies her abdomen, and encroaches considerably upon the thoracic cavity for periods of several months at a time, and which causes her mechanical relationship to her surroundings to differ from that of the male, the fœtus in her abdomen being also regarded as an external relationship rather than as a portion of the mother. The form and size of the foetal head, varying as it does in the same race as well as in the several races of man, may be considered as constituting a very varied and important mechanical relationship of the individual to its surroundings during the passage of the foetal head through the true pelvis. Therefore, we find that very considerable differences exist between the male and female types in the same race, and also between the female types of the same race and of different races.

The first attempt to throw light upon this important question of the causation of the many racial differences in type was made, I believe, by Sir William Turner.² He has endeavoured to elucidate some of the mechanical factors which affect the anatomy of each race, or, in other words, to determine the peculiar relationship of the individuals of each race to its surroundings. The researches that I have made into the very remarkable and considerable alterations in character which the normal anatomy of our race undergoes when the mechanical relationship of the individual to its surroundings is altered from the normal in a definite and measurable manner, would lead me not only to support Professor Turner's views very strongly, but also to carry the same line of argument much further.

I think that much error has arisen and that little progress has been made because many observers have too often been satisfied to try to arrive at general laws from the aggregation of a large number of so-called indices, etc., instead of pursuing the more scientific course of attempting to define the factors that determine the presence of the so-called normal condition of the skeleton from a careful study of the variations in form which exist in the individuals of the same race, as well as between the individuals of different races.

I have been able to explain on the simplest mechanical principles a great number of the deviations from the normal type which are found in our own race, and, from a consideration of such, I think that we are perfectly at liberty to assume that the anatomical differences which exist in the various races of man are explicable as regards their causation upon the same basis. I

¹ Read in the Section of Anatomy and Physiology at the Annual Meeting of the British Medical Association held at Glasgow, August, 1888.

² Report on the Human Crania and other Bones of the Skeleton Collected during the Voyage of H.M.S. *Challenger*, and other papers in the *Journal of Anatomy and Physiology*.

believe that it is by working in this direction that progress is to be made, and that it is by a careful study of the factors that determine every deviation from the normal type presented by the subject which bears an abnormal relationship to its surroundings, that we will be in a position to ascertain the mode of development of every detail in the anatomy of the organism which bears to its surroundings what we may regard as a normal relationship; or, in other words, a non-specialised relationship, and to verify absolutely the problem of evolution.

Fortunately, in the present condition of society, we have an almost innumerable number of experiments upon the normal subject made for us, and, from a study of these, we ought to be able to obtain a vast amount of information, and to make generalisations of great importance. The natural experiments to which I refer are the changes in the anatomy of the individual which are produced by the pursuit of some laborious occupation. There are very many trades in which the labourer is engaged habitually in performing a definite series or sequence of movements, each event of the sequence leaving a permanent and unmistakable impress upon the anatomy of the organism, the bones being altered in form very materially, the muscles in structure, and the articulations in their character and anatomical details. I allude to such workmen as ships-trimmers, coalheavers, shoemakers, porters of various kinds, milkmen, washerwomen, etc.

I do not think that anything can be more full of interest, or possibly more productive of good results, than the careful study of these changes. In discussing the variations presented by the skeleton, we are but too ready to shelve their causation if it is not at once obvious, and to fancy that we are explaining the mode of their production satisfactorily by asserting that they are retrocessions to lower types, examples of deficient or abnormal development, or the product of some disease.

While writing this, I have before me a very interesting paper³ on Variations of the Human Shoulder Girdle, by Professor Thomas Dwight, whose work is familiar to all of us. In that paper he has collected the varying indices of the scapula in many races of man and quadrumana. In discussing the lower angle of the scapula, he states that its form depends in part, though not wholly, upon the development of the surface to which the teres major is attached. He goes on to mention the usual slight projection from the axillary margin of this bone, which is occasionally very largely developed. He says that this process bears no direct ratio to the size of the teres major, and that the third trochanter on the femur is an analogous case, the occurrence of which, in his opinion, is quite uninfluenced by muscular development; also, that its existence in man is probably, as in the case of the third trochanter, the appearance of a peculiarity of a lower form. This quotation from Professor Dwight's paper brings me to the subject of mine, namely, the Result Produced by the Habitual Exercise of Considerable Strain upon Bones, Muscles, and Ligaments. In reference to the two conditions to which he calls attention, namely, the projection from the axillary border of the scapula and the third trochanter, my experience would lead me to conclude that the explanation which he gives of their presence is false, and that instead they have been developed as the result of excessive strain sustained habitually by the lower portion of the subscapularis, and by the psoas muscles respectively, bone extending along the tendinous attachments of these muscles, and in the direction in which traction is habitually exerted. I have never yet examined throughout the body which presented these or similar prominences in the attachments of muscles and ligaments without being able to satisfy myself completely that they are dependent for their presence upon the habitual transmission of excessive strain through these structures.

I need hardly remind you that in the normal subject, with advancing age, the abductor and extensor muscles cease to exert their functions fully before the flexors and adductors, and that, in consequence, the processes of bone upon which the former exerted strain during active adult life, and which were dependent upon the exercise of that habitual strain for their existence and continuance as prominences, disappear when that strain is no longer exerted. I would instance the atrophy of the tuberosities of the humerus, which takes place in feeble old age in association with the ascent of the head of the humerus from its normal position in relation to the glenoid cavity.

Before proceeding further, I would point out that the process

³ *American Naturalist*, July, 1887.

⁴ The Causation and Pathology of the so-called Disease Rheumatoid Arthritis and of Senile Changes. *Trans. Path. Soc., Guy's Hospital Reports*, etc.

of bone on the outer margin of scapula is produced by ossification extending along, and in the direction of traction exerted upon, the lowest intramuscular tendon of the subscapularis muscle, and that though the *teres major* arises by fleshy fibres from the surface of bone adjacent to the prolongation of the outer border, yet that muscle must obviously exert but a very slight influence upon its development. We must remember, at the same time, that the *teres major* is associated in its action with the lower portion of the subscapularis, and that, in consequence, the factors which determine the ossification of the lowest intra-muscular septum of the subscapularis muscle produce a similar ossification in the aponeurosis of the *teres major*, where it is attached to the inner limit of the flat surface of the scapula, from which its muscular fibres arise directly.

Here are the shoulder-girdles of a shoemaker, a sailor, and a porter, who carried moderately heavy loads upon his shoulder. The last example is not nearly as perfect as many I have examined, for the reason that the loads carried were not excessively heavy; it is, however, the best I can lay my hand upon at the present moment. They were all obtained from labourers who had been engaged during long lifetimes in the pursuit of very laborious occupations; and as they all died at a very mature old age, their skeletons presented varying degrees of degenerative changes.

A very superficial examination of these bones is sufficient to show that they differ among themselves in many particulars, as well as from the same bones in a subject which has never performed any heavy work. The scapula varies in its general form and size with the height of the individual, with the breadth of the chest and with the length of the clavicle. The details of its form vary in different subjects with the occupation, habits, or pursuit of the individual or his antecedents. Observe, for instance, the considerable breadth of the free outer margin of the acromion process in these three labourers, and notice that this abnormal breadth is most marked in the case of the shoemaker. This is produced by the great strain which is habitually maintained by the back part of the deltoid in these several occupations, and this is greatest in its constancy in the shoemaker, who is engaged in the heavy work of pulling waxed threads through holes in thick leather, for possibly twelve or fourteen hours a day, as in this subject. Therefore, we find that in the shoemaker the attachment to the scapula of the back parts of the centre of this muscle is extremely tendinous, and that the margin of the acromion is extended backwards, in order to afford a suitable purchase for its action, especially at the commencement of the sudden traction effort at which period the greatest strain is sustained.

For the same reason the humerus presents a very remarkable prominence in the seat of insertion of the deltoid, and particularly of the posterior tendinous attachment of that muscle. We must at once recognise the fact that the prominence of surfaces or of ridges in the attachments of muscles affords very little indication of the bulk of the muscle, or, in other words, of the muscularity of the individual, but that it varies directly as the amount of strain sustained habitually by the muscle, as does also the amount of tendinous tissue in its substance. A very little experience in the dissection of labourers and others will enable one to verify this statement.

I would call attention to the remarkable variations presented by the axillary borders of these three bones, as they demonstrate very clearly the factors which determine the extent of development of the projection referred to previously upon their outer margins.

The lowest of the tendinous intersections of the subscapularis is attached to the margin of bone which limits externally the lower portion of the surface to which the *teres major* is attached, and to the anterior of the two margins which are present on the rest of the outer or axillary border of the scapula. The smooth bone intervening between these margins or ridges attaches the fleshy fibres of the subscapularis, while the posterior of the two margins receives the attachment of the strong aponeurosis covering the *teres minor* and *infra-spinatus* muscles. This aponeurosis is attached lower down to the upper and inner margin of the smooth surface from which the *teres major* arises, and that muscle itself derives an extensive origin from this aponeurosis. In the shoemaker the lowest portion of the subscapularis sustains comparatively slight strain during the performance of the act of sewing, therefore we find that the anterior of the two ridges upon the axillary margin is but slightly developed, and lies internal to the posterior one in the whole of its length. For

the same reason the tubercle on the lower portion of the axillary margin is very small and insignificant.

In the sailor, who is constantly engaged in climbing, pulling on ropes, or turning a heavy wheel, very considerable strain is thrown upon the outermost tendon of the subscapularis, and also upon the *teres major*; therefore we find that the anterior of the two ridges on the axillary border of the scapula is remarkably prominent, that its lower portion projects outwards beyond the posterior ridge, and that the tubercle, which is situated at its lowest limit, forms a very sharp projecting rough angle. Owing to the projection of the anterior edge externally beyond the posterior, the lower part of the groove between the two ridges looks directly backwards, so that a portion of the subscapularis arises from what is, in this subject, the dorsal aspect of the scapula. The surface attaching the fleshy fibres of the *teres major* is increased in area somewhat, and the ridge to which the aponeurotic origin of this muscle is attached is remarkably sharp and prominent.

The specimens afford many other instances of the result of excessive strain exerted habitually upon certain muscles, but since the time at my disposal is short, I will not delay to consider them at present. I will now pass on to a more conspicuous condition, which occurs not very uncommonly in the lower limb. It is an outgrowth from the tibia and fibula into the intramuscular tendons of the soleus. A considerable amount of prominent roughness in these bones in the attachment of these aponeurotic structures is seen not uncommonly in the bodies of such as have been engaged in laborious pursuits, in which the soleus is subjected habitually to very great strain. Still better examples of this condition can be observed in the bodies of those in whom the soleus has been exposed habitually to excessive strain by some interference with the normal mode of transmission of superjacent weight through the lower extremity either by injury or disease. I have examined several of the latter, two of which were very marked. One I found in a man, whose right hip-joint had become ankylosed by bone in early life from disease at a right angle to the trunk, and the other in a man whose tibia and fibula had been fractured low down, the foot and lower fragments having been rotated outwards. The former subject had evidently done a good deal of light carrying work during his lifetime, while the loads carried habitually by the latter were very great, and were borne upon the back.

In either case there projected from the fibular attachment of the outer intra-muscular rupture of the soleus a prominent mass of bone which was directed obliquely downwards and backwards for about an inch. In the case of the heavy labourer this process was shorter and of denser structure than in the subject with the ankylosed hip. There was also upon the oblique line of the tibia a shelf of bone about a third of an inch long. It ran in the direction of and attached by its surfaces and free margin the internal intra-muscular tendon of the soleus.

In both instances it was quite obvious that the mechanical conditions brought about by disease in one case, and by injury in the other, exposed the soleus habitually not only to the transmission of the normal superjacent weight of the trunk under unfavourable conditions, but also the added weight of the loads carried. Therefore the soleus was in the habit of sustaining an amount of strain which was greatly in excess of what is normal, or in other words, of that which evolved the condition of anatomy which the vast majority of human beings possess.

In a similar manner, when a constant and considerable strain in one direction is thrown upon a ligament, its fibrous structure shows a marked tendency to become converted into bone. This conversion takes place in one or both of two ways, namely, by the development of a separate piece of bone in its substance, which may subsequently articulate or fuse with the adjacent bone or bones, or by the growth of bone into the substance of the ligament from the bony surfaces to which it is attached. These processes of bone in some cases fuse with one another, or in others with the separate developments in the ligament. Both these processes are well exhibited in the labour changes that ensue in the supra-spinous and inter-spinous ligaments and in the *ligamentum nuchæ*, etc., of the coalheaver or other heavy porter who carries in a similar manner, and though these tension changes are not characterised by the same amount of bone formation and ankylosis as are those resulting from the direct transmission of pressure, and though the causation of the former is less obvious than that of the latter, they follow on the same very definite lines, forming, like them, an evolutionary process, which is up to a cer-

tain point advantageous to the individual in performing his particular form of labour.

When the normal mechanical condition of the body is altered, the transmission of the body weight alone may be sufficient to produce ossification of the ligaments, which sustain an abnormal amount of weight habitually. For instance, in more than one well-marked example of dorsal excurvation acquired early in life, I have found a good-sized piece of bone in the hypertrophied ligamentum nuchæ, as well as considerable prominence of the bony attachment of that ligament to the occiput.

THE POSITION OF THE MAMMALIAN LIMB, REGARDED IN THE LIGHT OF ITS INNERVATION AND DEVELOPMENT.¹

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Introduction.—In its earliest condition the mammalian limb shows no signs of segmentation. The bones and joints, muscles, and vessels, are developed from mesoblast formed *in situ*, and are primarily distinct and separate from the segmented trunk. The nerves alone are segmental, and they moreover precede, in order of time, the development of muscle and skeleton. From a consideration of the nerves, we can form an estimate of the position of the limb and its relation to the trunk. The nerves in a sense represent segments. The limbs are outgrowths corresponding to the ventral and lateral portions of the cylindrical trunk, as seen by their innervation,—from the whole of the inferior primary divisions concerned, and not the lateral branches alone.

Position of the Fore Limb.—In mammals, the fore limb has a fairly constant position, and the exceptions are nearly all alike. The proximal end of its postaxial border corresponds to the first thoracic segment, and is innervated by the first thoracic nerve in nineteen out of twenty-five cases. In six cases the second thoracic segment is implicated. The latter cases point to a tendency on the part of the limb to shift backwards. The preaxial border varies in different cases, extending forwards more or less towards the head. This view is supported by abnormal cases in man, by cases like the manatee, with an abnormal number of cervical vertebrae, and by the condition of things met with in birds. In birds, Fürbringer shows there is a tendency towards a shifting of the fore limb in a caudal direction.

Position of the Hind Limb.—The position of the hind limb varies more in relation to the axial skeleton than that of the fore limb. The postaxial border, reckoned by the position of the last nerve entering the great sciatic nerve (*n. bigeminus* of Ihring), corresponds to one of four segments—second sacral, first sacral, last lumbar, or third sacral. In only two cases was the third sacral segment found—man and the ass. The adult position of the limb does not always correspond with the developmental position; for example, in the porcupine the last nerve to enter the sacral plexus is the last lumbar. In most cases the limb remains in direct connection with the segments with which it is developmentally connected. In these cases in which the limb girdle is articulated with segments behind those with which it is developmentally associated, the inference is that the limb has shifted backwards in process of development. In those cases in which, as in the ass, the number of sacral nerves entering the sacral plexus exceeds the number of “true” sacral vertebrae, the inference is that the limb has shifted forwards, so as to become attached to segments placed anteriorly. This view is supported by: 1. Cases of increase or diminution in the number of thoracic-lumbar vertebrae. 2. By the condition of things met with in reptiles, and birds (in which Gadow shows distinctly the tendency of the limb to shift backwards), and 3. By the cases met with of congenital scoliosis, in man and animals.

Conclusions.—1. That the segmental spinal nerves which enter and supply the limbs afford the most trustworthy guide to an estimation of the position of the limbs. 2. That from the evidence afforded by the nerves the position of the limbs is not constant. 3. That the position of the mammalian fore limb varies very slightly, but that it shows a tendency to shift backwards towards the hinder end of the body, from the point where it is developed. This conclusion is supported by Fürbringer's researches in birds. 4. That in mammals with an abnormal number of cer-

vical vertebrae, the irregularity is to be explained, not by the omission or interpolation of vertebrae, but by a shifting of the limb, and a correlated difference in the development of associated parts. In the manatee, for example, the presence of six cervical vertebrae is explained by the condition of the brachial plexus, which shows that either the fore limb is developed in this case further forwards in the neck; or it represents an archaic condition. 5. That the position of the hind limb is less constant than that of the fore limb. It may remain opposite the segments with which it is embryonically connected: but in mammals it displays in most cases a tendency to move backwards, like the fore limb. This conclusion is strengthened by the work of Gegenbaur, Gadow, and Mivart, in birds and reptiles. 6. That in consequence of this process of shifting, other correlated and concomitant changes occur in associated parts. The “sacral” vertebrae, therefore, do not necessarily, from a developmental point of view, correspond to segments concerned in the origin and growth of the limb. They are merely those bones with which the ossa innominata are articulated, and may not be strictly homologous with the corresponding bones in another individual or species. They simply serve a similar purpose in supporting the limb girdle. 7. That in certain exceptional cases, as in man, there is a tendency for the limb girdle to shift forwards in relation to the axial skeleton, along with a concomitant shortening of the vertebral column.

ON CONGENITAL DIAPHRAGMATIC HERNIA.¹

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Introduction.—Cases of diaphragmatic hernia, arising from whatever cause, are rare enough to make them objects of interest to both the anatomist and the surgeon. They are so seldom met with in practice, indeed, that our standard works on surgery either dismiss them with scant notice, or omit all mention of them. The best systematic account of the condition which I have been able to meet with is that by André Boursier.²

The forms of diaphragmatic hernia are three—traumatic, acquired (or spontaneous), and congenital. The traumatic variety, caused by wounds or lacerations, is generally fatal, either immediately from strangulation, or subsequently from inflammation of one of the serous membranes. The acquired or spontaneous form is due to the same causes as give rise to other ruptures, and may produce no symptoms, as it very frequently interferes in no way with the vital functions. The congenital form is without doubt the most interesting to the anatomist, chiefly on account of the light it throws on the mode of development of the diaphragm—a subject which, in spite of our recent advances in embryology, yet presents much difficulty.

These ruptures may be classified in diverse ways, according to the amount of interference with the vital functions to which they give rise; according to their position; or according to the mode in which the opening of the hernial sac is formed. Adopting the last-named classification, we find there are three principal varieties met with:

1. Due to defective formation of the diaphragm.
2. Occurring through one of the natural openings.
3. Due to distension of the fibres of the diaphragm.

1. **Defective formation of the Diaphragm.**—*a.* Total absence of the diaphragm is extremely rare. Cases are recorded by Meckel,³ Bowditch,⁴ Duguet,⁵ and Diemerbroeck.⁶ The last case must be regarded with suspicion, as it is stated to have occurred in a boy, aged 7. *b.* Partial absence of the diaphragm is the most frequent cause of congenital hernia. The rupture is generally placed laterally, and is on one side only. A few cases are recorded in which it occurred on both sides (Bowditch,⁷ Willigh,⁸ etc.) Duguet⁹ denies that a congenital hernia can be placed mesially; one case, at least,¹⁰ points rather towards the fact that this asser-

¹ Read in the Section of Anatomy and Physiology, at the Annual Meeting of the British Medical Association, held in Glasgow, August, 1888.

² *Dict. Encyclop. des Sci. Méd.*, Tome xxix, Art. Diaphragme.

³ Meckel, *Anat.*, vol. iv.

⁴ Treatise on Diaphragm. Hernia, *Charleston Med. Journ. and Review*, May, 1855.

⁵ *De la Hernie Diaphragm. Congénitale*, Paris, 1866.

⁶ Diemerbroeck, quoted by Boursier, *loc. cit.*

⁷ *Loc. cit.*

⁸ Willigh, *Journal Trimestriel de Prague*, 1856.

⁹ *Loc. cit.*

¹⁰ Bednar, Vienna, 1852.

¹ Read in the Section of Anatomy and Physiology, at the Annual Meeting of the British Medical Association, held in Glasgow, August, 1888.