THE SHATTUCK LECTURE.

THE RANGE AND SIGNIFICANCE OF VARIATION IN THE HUMAN SKELETON.

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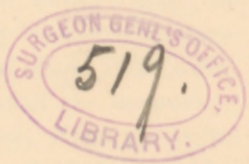

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THE RANGE AND SIGNIFICANCE OF VARIATION IN THE HUMAN SKELETON.

In 1878 an essay on the Identification of the Human Skeleton had the good fortune to receive the Shattuck Prize offered by the Massachusetts Medical Society. It is fitting that the same line of thought should be developed in the Shattuck Lecture.

In that essay were discussed the recognition of the sex and age of the skeleton, the method of estimating the height and of making proper allowance for such parts as might be wanting. To some of these questions I brought methods of my own, but for many points I was forced to rely on the statements in books, too often quoted one from another. No part of medical literature is so perfunctory, artificial, and altogether unsatisfactory as medico-legal anatomy.

During my professorship at the Harvard Medical School I have tried to use the material for original investigations, to find new criteria of sex and of age, to observe the degree of asymmetry between the two sides of the body, to learn how frequently anomalies occur which would vitiate the usual methods of procedure, and finally to study the question of the relation between the external shape of the body, its peculiar individuality, and the shape of the supporting framework. Though, as I hope to show, these researches have not been fruitless, yet some of these fields have yielded little. Attempts have exceeded performances. But if the man is to be pitied who can travel from Dan to Beersheba and cry "'Tis all barren!" much more is the anatomist worthy of compassion whose studies in the dissecting-room show

him nothing but dry details of the structure of the body. It is his own fault if he brings no fresh learning to the great topics of the day. In these studies I have seen many luminous facts throwing light on the relations of the bodies of man and lower animals, on the peculiarities of prehistoric man, and on the process of development and growth. I shall not leave these quite without notice; but, speaking as I am to a medical audience, rendering as it were an account of my stewardship (for what is a professor in a Medical School but the trusted servant of the profession?), I shall bring into strongest relief those parts of the inquiry which are of most practical value in medico-legal questions. It would require a course of lectures, rather than a single one, to follow the steps of my investigations. I wish as much as may be to spare my audience the details, giving only the results. I shall not, however, confine myself exclusively to my own work, as it is my purpose to show the present state of our knowledge.

In living nature each species suggests a more or less ideal type, the exact counterpart of which the student often searches for in vain. This type is not the expression of the mean development; it is far above that. It is the perfect individual. It is what in a show of animals or plants would be called a "prize-winner." It is in such a specimen that we would study the relative development of the different parts. We shall never reach this by compiling the means of vast numbers of specimens. This latter method, however, if exercised with due care and discretion, will give us, not the type of the animal or plant as shown at its best, but the one most commonly met with. These two conceptions must not be confounded, for they are two different things, each of which has its place and its uses. When we come to Man, one ideal type is not enough. We should have to take each race by itself, were it not that I am dealing with the Caucasian alone. The differ-

ence caused by sex, however, requires one type for man and another for woman. Indeed, it may be said in parenthesis that this shows admirably the difference between the ideal and the average. What sort of a human figure would be reached by an average of measurements of males and females? This principle hereafter with advancing science must be carried even further, so as to recognize sub-types such as the tall, the short and the intermediate.

But nature shows the student more than the type and the mean. It even disguises them by numberless variations in many, often in opposite, directions.

The Sex.

Turning at length to the human skeleton, we find as in the whole body, two types, a male and a female. The typical skeleton reveals its sex so distinctly that none but a tyro would need measure and compass to find it. But to the anatomist there are many signs which to others are unknown, by which almost every bone in the body reveals its sex. This is not to say that it is always easy or even possible to decide on the sex of a skeleton. Far from it. We are confronted here with the effect of variation. The mean male or female skeleton is of course less easily recognized than the typical one. Then come those which have fewer and fewer characteristic points, till we find a certain number of which the diagnosis is very difficult or even impossible. My studies have been specially directed to these cases, among which we may reckon skeletons of which the most characteristic parts are wanting.

The sex has always been determined by the pelvis. I can reiterate my remark of sixteen years ago, that it is for that purpose of more value than all the rest of the skeleton. There is little or nothing to add.

The female pelvis is broad and the male deep. These remarks apply, however, chiefly to the true pelvis. There

is some discrepancy in the statements, as to the transverse measurements of the false pelvis. While I believe it is true that as a rule the anterior superior spines of the ilia are farther apart in woman, I question very much whether this is true of the most distant points of the iliac crest. Should the pelvis be wanting or too little typical to be conclusive, for such there are, we must turn to the general sexual characteristics of bone, which indeed will help us with the pelvis itself.

There is the male and female type of bone, there are the proportions of the body (which, however, are not of much use if the bones are separate), and there are the peculiarities of each bone. Of course the spheres of these different criteria fuse, one with another.

First, as to the general male and female characteristics. We all know that male bones are larger, stronger and more curved. Their ridges and projections are greater and rougher. It seems to be tacitly assumed that, excepting the mere size, these features depend on the greater muscular development of man. This I do not believe is the fact, at all events among civilized races. My observations go to show that female bones rarely assume the male development. I never find, even in the strongest, the same rough surfaces and ridges, rarely the same thickness. There is one sign which has received little attention and which repays research. It is the small size of the female articular surfaces. I shall return to this again and again, for it is of the greatest significance, and, as all the bones have joints, of the widest application.

Next, as to the proportions of the figure. The small thorax, both short and narrow, is essentially female. While it is true that the lumbar region of the spine is relatively longer in woman, the chief factors in the shortness of the thorax are the short sternum and small lower ribs. Add to this the relatively slight development of the upper ex-

tremities, and we are ready for the study of the individual bones.

The sex of the skull is very often fairly easy to determine. The relatively small size of the face, the lightness of the jaws, the small size of the superciliary eminences, of the occipital protuberance and ridges, and of the mastoid processes of the female are very suggestive. One feature, which I think of much value, is the more sudden change of direction from the forehead to the top of the skull in woman. Another, which we owe to Professor Cleland, is the more marked elevation above the occipital condyles in man, which throws the face higher up, departing more from the infantile condition which lingers in woman, as is shown by the more prominent frontal and parietal eminences. As a specimen of the male skull I show one which its late occupant would have been glad to have so used,—that of Spurzheim, the phrenologist.

The studies which I have undertaken on bones of the trunk and limbs must be given at some length. In my previous essay I had discussed on the basis of a very small number of observations of the STERNUM, the value of Hyrtl's law that "the manubrium of the female sternum exceeds half the length of the body, while the body of the male sternum is, at least, twice as long as the manubrium." I found then, curiously enough, that the averages of my measurements confirmed that law, but that the exceptions were equal to the cases in accord with it. More curiously still, I found this result repeated in a series of measurements large enough to be satisfactory (those of 228 bones), with the difference that the exceptions amounted to almost precisely 40%. Thus, though the law still held true in averages, it would fail to apply to two bodies out of five, and thus would be useless for the determination of any particular case. Farther, as yet unpublished, observations have raised my numbers to 342 sterna, of which 222 were male

and 120 female. My results once more confirm Hyrtl's law for the mean, but still approximately forty per cent. of the cases are exceptions, owing to the variability of this bone.

Strauch found in addition that in male and female sterna of equal length, the former is narrower in the manubrium and in the lower part of the body. According to him the female sternum is relatively (but not absolutely) broader than the male one. Hence we conclude that though averages may deceive us, yet it is possible to recognize very distinctly a male and a female type of breast-bone. The former with a relatively long and regular body, the lower parts of which are well developed, separating the attachments of the lower cartilages, the latter with a shorter body, broadened below and having depressions of the lower cartilages close together, indicating a want of development of the lower sternebræ. Intermediate forms of difficult diagnosis must occur. In these I should look for relatively large or small clavicular facets as signs of male or female sterna respectively. Here are more or less peculiar specimens. In this, which happens to come from a negress, the body ends opposite the fourth or fifth cartilage.

The separate bones of the spine and ribs offer little that is of practical value.

The whole upper extremity is much lighter in woman. The lighter shoulders rest on a smaller and relatively narrower thorax. The collar-bones are very characteristic. Strong, long, and boldly curved in man, they are slight, short and straighter in woman. The degree of curve is less characteristic than some other features, as we sometimes find slight but strongly curved clavicles in woman and strong straight ones in man. This depends on the peculiarities of the figure. The largeness or smallness of the articular surfaces is of much importance.

The Shoulder Blade is an extremely variable bone.

To me it is very interesting. I imagine that I shall surprise my hearers in speaking of its sexual characteristics as very remarkable. The scapular index, that is the ratio of the breadth to the length, need not be discussed, though I have measured 198 bones for this paper. Its sexual significance is practically nil. In a previous paper I have given drawings of two widely different scapulæ with almost identical indices.

While it is very difficult to state what, beyond small size and delicacy of build, constitute the sexual characteristics of the female scapula, yet there is no question that in well marked cases it has a characteristic type. In my opinion a competent expert can decide with great probability the sex of the scapula in at least four out of five of a considerable number of bones taken at random.

The mere question of size is an important one. I have examined the bones of 123 bodies, 84 male and 39 female, in which the height and breadth of shoulders were known, and have taken the length, breadth and index. By far the most useful of these measurements is that of the length, as shown in the following table:

LENGTH OF SCAPULA.

	Male.	*Female.*
LENGTH OF BONE.	NUMBER.	NUMBER.
From 13 to 14 cm.		10
" 14 " 15 "	3	13
" 15 " 16 "	10	11
" 16 " 17 "	32	5
" 17 " 18 "	30	
" 18 " 19 "	8	
" 19 " 20 "	1	

Average length of male bone, 16.8 cm.
" " " female bone, 14.7 cm.

As the two sides usually differ, I have in this series always taken the longer bone.

Thus it appears that of 123 bones 26 measure less than 15 cm., of which only 3 were male; also that 76 measure 16 cm. or more, of which only 5 were female. There is no single instance of a bone measuring less than 14 cm. being male, nor of one measuring 17 being female. It is needless to say that exceptions would be found in a very large series, but these limits are very valuable.

I have studied the dimensions and proportions of the glenoid cavity on 90 bones, of which 63 were male and 27 female. In brief, the female socket is not only smaller but relatively narrower. The average male length is 3.92 cm., and the female 3.36. Very few male sockets are less than 3.6 cm., and very few female ones as long.

When it comes to examining the various parts of the bone, one by one, it is very difficult to find sexual characteristics that will stand rigid examination; none the less I have little difficulty in defining a typical female scapula. It is more easy to do so than to define a male one, as the latter is more variable. The greatest length should not exceed 15. cm., and that of the glenoid should be about 3.4. The latter should look narrow and delicate. The inferior angle is sharp, the posterior border straight as far as the spine, its upper portion inclining forward. The upper border shows a sharp descent from the superior angle to the supra-scapular notch. The process for the teres major at the lower end of the axillary border is small. The coracoid is remarkably delicate, its end is compressed instead of knobbed. The acromion is narrow, of the shape called falcate by Prof. Macalister. In the male the lower angle is broader, the teres major process more developed. The posterior border is rather more rounded, the upper border more horizontal and higher, so as to make a larger supra-spinous fossa, the coracoid is thick with an approach to a knob at the end. The acromion larger, squarer, with a large clavicular facet.

In view of the considerable difference in size already mentioned, it is plain that the sex of most shoulder-blades may be determined by that alone beyond reasonable doubt. Many bones, however, are of the doubtful size. These, in my opinion, can for the most part be sorted out by an expert. A small residue is not to be recognized. A bone the sex of which cannot be told is more likely to be male than female. We may feel reasonably sure that it does not belong to a tall man or a short woman. There are exceptions to all rules. Here is a female scapula which both in size and shape is distinctly masculine, yet it came from a short and fat old woman with a short neck and high shoulders. It is perhaps relevant to state that she was insane; as it is thought that structural peculiaries are often found in the deranged.

The female humerus, radius and ulna show far more strikingly what I have called the general femininity of their structure, than the bones of the thigh and leg. Though I do not in this case speak by the book, that is by measurements, I believe that the difference of size is greater between male and female humeri than between the femora. It is generally thought that the female humerus is more slanting than the male, that is to say makes a smaller lateral angle with the extended and supinated fore-arm, but Berteaux's measurements make the difference too slight to be worth much. The articular ends of bone of both arm and fore-arm come to the rescue, but I regret that I have no series of measurements large enough to quote.

The Femur has rightly received much attention. It is a favorite of anatomists. I have, therefore, the advantage of valuable observations of others to compare with my own. I may in particular refer to the works of Humphry, Broca, Mikulicz, Charpy and Berteaux. The monograph of the last on the humerus and the femur is a mine of information. Leaving aside the length of the femur, let us take certain parts.

My observations on these details are founded on 64 cases, 38 men and 26 women, in which the body was measured before dissection and the bones studied in detail later. The length of the neck of the femur is on the whole in direct ratio to the length of the shaft. That of woman is therefore on the average the shorter, but there is no relative sexual difference worth noting. Berteaux has shown moreover that the relation of the thickness of the neck to its vertical breadth is the same in the two sexes. The angle which it makes with the shaft has long been a moot point. It has been taught that it is less (that is to say nearer a right angle) in shorter femurs, and if a short femur joins a broad pelvis, as in woman, by so much the more is the angle decreased and thus the angle is smaller in woman. This is diagrammatic demonstration which I long taught with perfect good faith. Of late years, however, it has been disputed by several observers, some even maintaining the reverse. My own observations, taken with others, convince me that there is probably no sexual significance in the angle (with one reservation to be presently set forth). The average in the two sexes is about the same, that of the women being indeed in my series a trifle the greater, thus in men 125.1°, in women 125.6°. Like every one else I find that there is a great individual variation, ranging from 110° to 144°. Be it noted by the way that the lowest is in a man and the highest is in a woman. But in the male bones there seems to be no regularity in the distribution of these variations. In man a long or a short femur is about equally likely to have a large or a small angle; but the shorter female ones tend to a lower angle. There is, therefore, this much truth in the old idea, that the shortest, but but I do not say the most typical, female femurs have angles below the average, as proved by the following observations. The average angle of the longer half of the male bones is 126.5°, and that of the shorter 123.6°,

while the longer and the shorter halves of the female series give 129.2°, and 121.9° respectively. It appears also that the highest angles of all are in the longest female femurs, but I doubt whether this connection is so regular as that of the short ones. This shows, however, that as a whole this angle is of little value as a sign of sex.

Another angle which has been thought to have more or less significance is that of the shaft with a vertical line, which according to the old theory should also be greater in shorter bones and wider pelves, and therefore associated with a smaller cervical angle. An analysis of my tables shows no system of relation between these angles. On the other hand the average inclination is a little less in the male than in the female, being 9.3° and 10.6° respectively. This is too small to be of any practical value, especially as the individual variation is very great.

Some other measurements seem to throw more light on this matter. They tend to establish the theory that the small size of joints is characteristic of woman. They are the greatest diameter of the head of the femur and the greatest transverse breadth through the condyles. The average diameter of the male head is 4.8 cm., that of the female 4.15. My tables show one marked difference between the sexes; namely, that in the women there is a fairly regular increase in the size of the head corresponding with the increase in length of the femur. Among the men this is not so. While it is true that most of the largest heads are found in the longer half of the bones and most of the smallest in the shorter half, the correspondence is far less evident. I find, moreover, that but two of the male bones have a diameter of less than 4.5 cm. and but two of the female a greater. Both these female bones were among the longest, but the two male were but a little below the average. Thus it would seem that the actual measurement of the head of the femur is a pretty good criterion of the

sex. The measurements of the knee are less conclusive. The average difference is just under one centimetre (8.3 and 7.3), but there are more that overlap.

Moreover there is a peculiarity in the shape of the typical male and female thigh bones which defies mathematical statement, which indeed I found very difficult to define long after I was aware of its presence. It is not merely that the typical female bone is more slender, as in fact everybody knows, but that seen from the front it has a peculiar outline. The shaft narrows gradually from the condyles till at, or above its middle, a part is reached that is narrower than elsewhere, above which there is a much less evident expansion. The typical male bone narrows much more suddenly from the condyles, so that the stout shaft soon reaches a tolerably uniform thickness. A rear view shows more distinctly that the male peculiarity seems to depend on the greater lateral projection of the outer condyle. Exceptions are plenty, but for all that there seems to be a pretty distinct difference of type, which with the help of certain measurements should enable us to determine the sex in most cases. I may mention that with the exception of a third trochanter (of the true kind) peculiar forms of femur are almost always male.

The tibia is in many respects a very variable bone. As a rule its greater delicacy of structure in woman is very plain. The smallness of the articular surfaces is striking. It is easy for an expert to judge rightly of its sex in most cases, though beyond the signs mentioned there is nothing absolutely characteristic.

While it appears from this discussion that there are certain mathematical considerations of great value in determining the sex, I would say emphatically that I consider the intelligent familarity with bones which develops what might almost be called an instinct, more trustworthy than hard and fast rules, resting on the dreary accuracy of statistics.

I have here bones from two widely different bodies which are interesting in this connection. One was an uncommonly good, even a graceful, figure of a young woman, were it not that the shoulders were somewhat too square and heavy. The bones are all remarkably graceful, though rather strong. The femur has the characteristic female outline. In spite of the comparatively heavy shoulders the scapulæ and humeri are distinctly feminine. The other was one of the largest and most powerful looking female bodies I ever dissected, except that the hands and feet were small. She had been a factory hand. The femur is an uncommonly powerful bone for a woman, but the small head, as well as its outline, suggests the sex. The bones of the upper extremity are evidently female. The slight development of the shoulders in women is therefore a recognizable feature in the bones. Contrast the bones of this large woman with those of a slight young man, of whom more later.

The Age.

The diagnosis of the age of bones (children not being considered) resolves itself into the study of processes occurring at three periods: first, that of late adolescence and early maturity; second, that of mature and middle life; and third, that of advanced age.

For the first period our guides are chiefly the union of the epiphyses, and that having occurred, the condition of the line of junction. I have not had the opportunity of making extensive observations at this age, but it is remarkable that so far as they go they all point one way, namely, to the earlier union of distinct parts than accords with the general teaching, and to the speedy disappearance of the epiphysial lines.

I agree with Topinard in looking on our knowledge as very unsatisfactory, but I cannot accept his provisional

table, which to my mind puts the dates of union much too late. The following table, giving the time of union of the epiphyses of the long bones compiled from English anatomies, is much better, but still wrong in the same direction.

From 16 to 18 lower epiphyses of humerus (except internal condyle) upper ends of radius and ulna, lesser trochanter of femur.

At 18 internal condyle of humerus, great trochanter.

At 18 to 19 head of femur, lower end of tibia.

From 20 to 21 or 22 head of humerus, lower end of radius and ulna, condyles of femur, lower end of fibula, upper end of tibia.

From 22 to 24 upper end of fibula.

My observations on a comparatively small number allow me to offer the following as a provisional chart from 17 on.

At 17 things are much as described as from 16 to 18, but perhaps a little more advanced. The lower end of the humerus is joined, excepting possibly the inner condyle.

Subsequently the process is more rapid, so that the epiphyses of the long bones are usually firmly joined to the shaft at 19. At this age the lines of union about the elbow and hip and ankle are nearly gone. At 20 all are indistinct or quite wanting. As for other parts, the basilar process of the occipital joins the sphenoid at the surface at from 17 to 19, the suture inside the skull being usually closed by 17. Once at 19 I saw the internal suture closed, but not the lower, and on section found a considerable piece of cartilage intervening. In another of the same age, which, however, was not split, there was no trace of a suture. The union of the pieces of the sacrum may be nearly finished at 17. The epiphyses of the crests of the ilia and of the posterior border and inferior angle of the scapula are among the last to unite. They probably join at about 21, but the lines of the crests of the ilia may be seen in parts for some years. As Topinard remarks, in-

dividual variations are many. I have several bones from a male skeleton which would seem much younger than those of others of both sexes of the same age. The fact is that this boy of 19, whose bones correspond very well with the usual statements, is the most backward specimen I remember. I think it is pretty certain that in the female the process is completed earlier. I do not agree with Topinard that it is completed earlier in the lower than in the upper extremity.

As I have had occasion to point out, the statements as to the time of the union of the different parts of the body of the sternum found in most text books are very far from correct, apparently having been copied and recopied. I am glad to find a great modification in the recent editions of the leading English anatomies. The union of the four pieces of the body begins from below, the fourth joining the third by 15 years or earlier. The union of the other parts of the body is completed by the age of 20. I have seen it completed at 16½ and at 19 (but not always). In a girl of 17 I have found the first piece of the body distinct, the others being united. I cannot distinctly remember ever having seen the body of the sternum of a white in more than one piece after 20, but once in a man of 46 the union of the first and second pieces of the meso-sternum had but just begun.

For the long succeeding period from maturity to marked decline three chief criteria may be considered, namely: first, the union of the different pieces of the sternum and the progress of ossification of the ensiform cartilage; second, the closure of the cranial sutures; and third, the co-ossification of the horns of the hyoid with the body.

The sternum having reached its normal condition of three pieces at 20 (and probably often earlier), the next change is the appearance of ossification in the ensiform cartilage, which may after this occur at any time and is no indication

of even middle age. This condition of affairs, namely, a meso-sternum in one piece, a distinct manubrium and ensiform, the latter more or less bony, usually persists throughout life. It exceeds fifty per cent. of my observavations on about 150 bodies. As these were on the average much above middle age, it is probable that this condition is even more common. In many cases the ensiform becomes one with the body. Though more frequent after middle age than before it, this is a sign of little value, for it is hard to say when this occurs. It rarely, however, begins before thirty. Union of all three pieces into one piece of bone is uncommon, occurring in less than 10%. This condition is probably dependent on constitutional tendency rather than on age, for in most of the cases which I have seen it apparently occurred before 50. I have met with it at 25 and at 28. Union of the manubrium and body with a free ensiform is even more rare than the last, of which it is presumably a preliminary stage. I may note as a sexual difference that the three parts of the breast-bone have a greater tendency to fuse in man than in woman.

The time of closure of the cranial sutures (by which I refer to the three great sutures of the vault) is very uncertain. Perhaps this simple statement would suffice, were it not that rules have been given to determine the age of the skull from the condition of the sutures. In 1890 I published my observations on 100 skulls. The process of co-ossification begins on the inside of the skull. It usually begins at about 30. The order and rate of closure are very varying. Complete closure may occur at any time. I have an instance of it in this thick calvaria of an epileptic black boy of 15. It does not necessarily depend on the thickness of the skull, for one of a girl of 20 in which they are all open is nearly as thick. Here is the calvaria of a woman of 52 on the outside of which the sutures appear open, though they are mostly closed within. The sutures may

be distinct or open in old age, but I consider an abnormally early closure much more frequent. Partially closed sutures alone do not indicate an age much above 30. Sutures absolutely open in most cases mean an earlier age.

My observations on the hyoid embrace among whites only 44 men and 20 women. The lesser horn is often rudimentary or wanting. It may be connected by either a joint or a ligament. Its union to the body by bone is uncommon, and when it occurs is a sign of advanced age. I have seen both lesser horns fused with the body only once before fifty, in a man of 31. Our chief guide is, therefore, the great horns. I have seen them both joined only six times out of 31 subjects under 45 (all but two of which had passed 20). After 45 years both are joined in more than half the cases. They may, however, be free in extreme age.

The general changes in the bones in later life are vague and ill-defined. The atrophy, which is often seen in the bones of the very aged, begins at no definite period. I have in my collection bones of persons over 70 which cannot even on section be distinguished from those of early maturity. In extreme age atrophy is, of course, to be expected.

The skull shows a marked atrophy of the face with an enlarging of the angle of the jaw, especially when edentulous. The cranium itself does not show the same wasting as the face, but on the contrary may be thickened. The idea that the angle of the neck of the femur is diminished is no longer held. The ossification of cartilage, the closure of sutures, increased roughness along lines of insertion of tendons, are often changes due rather to constitutional causes than to age. Their significance must be carefully weighed.

While I have felt justified in speaking with greater confidence on the determination of the sex than I did sixteen years ago, in the question of age it is just the reverse.

Asymmetry.

The question of asymmetry of the limbs requires brief mention. I have measurements of the separate bones of about 75 subjects, of which rather more than two thirds were male. As to the arm, the right humerus is almost always the longer, and the right radius usually; the combined length is almost always greater on the right. I find the average difference 6 mm. Rollet, who measured the bones of 50 male and 50 female subjects, puts it at from 7 to 8 mm.

As for the legs, the femurs differ about 2 mm., one side predominating about as often as the other, the tibiæ by some 3 mm., the left side being more often the longer. The combined length is greater on the left in distinctly more than half the cases, the average excess being from 4 to 5 mm. Rollet makes the differences somewhat greater and apparently finds that neither side is particularly favored. The two longer bones of a limb are usually on the same side, but not always. Wright's measurements on legs on the living and Garson's on skeletons, each gives the predominance to the left limb. My observations show an equality between the sides of the body that is greater than I had anticipated.

I may mention that incidentally to this investigation I have been able to carry some light where it is much needed, namely, as to the value of measurements on the living, but this is foreign to the present discussion. How far inequality of the central nervous system may be correlated with that of the limbs is one of those questions on which surmises far exceed exact knowledge. I have here the base of a female skull showing almost extraordinary asymmetry in favor of the left side, yet the bones of the right arm exceed those of the left by 1 cm., which though uncommon is hardly remarkable, and the bones of both legs are pecisely equal.

The Estimation of the Height.

If it be asked how far individual variations may affect our success in estimating the height, the answer must depend on the method that is employed. If we follow the best, or anatomical method, namely, that of putting the bones into proper position, making due allowance for soft parts and measuring the height, the individual variation does not count, because the problem is distinctly under the eye. But if parts are wanting so that we must turn to the method of calculating by proportions, individual variations are of the greatest importance. Indeed, they are so important that they make absolute certainty almost impossible. Should the legs be wanting we must turn to elaborate tables which I have calculated to enable us by multiplying the length of the spine from atlas to sacrum by certain coefficients for each sex, to obtain the height; sometimes with wonderful exactness. Still, not only does the length vary considerably, but the number of anomalous spines observed is increasing. Those with six lumbar vertebræ are common enough. My tables show that usually this increases the proportionate length of the spine, but not invariably. Thirteen and eleven thoracic vertebræ without corresponding decrease or increase in other regions are occasionally met with. Then we have the proportions reckoned from the height of the pubes, and finally from the separate bones. From large numbers of subjects measured in our anthropological laboratory, both before or after dissection, I selected forty, twenty male and twenty female, in each of which the humeri, radii, femora, and tibiæ of both sides had been measured. From these I calculated the height according to my own tables from the spine; according to the methods of Topinard, Rollet and Manouvrier from the humerus, radius, femur and tibia. The height may be reckoned from any one of these bones, but I have pur-

sued the method of taking the average length of the bones of both sides, and having found the height from each of humerus, radius, femur and tibia, to take the average of the four as probably the nearest approach to the true height. I have repeated this process according to the method of each of these three observers.

Not to stop for details, it appears that by almost any of these methods we can come within 2.5 cm. or 1 inch in about half the cases, within 5 cm. or 2 inches in about three fourths of them, which leaves one fourth remaining in which the error is serious.[1]

The Skeleton and the Figure.

What relation, if any, there may be between the shape of the bones and that of the body, is a very interesting question, which under certain circumstances may well become a momentous one. Can we from our knowledge of a person's figure predicate at least the general character of his bones, and conversely if bones are laid before us can we say anything worth saying as to the soft parts that once clothed them? Surely, putting aside extraordinarily tall or short or peculiar figures, the part we should expect to show the greatest individuality is the skull.

A typical long and a typical broad skull are of course readily distinguished. There are also typical long and narrow and typical short and broad faces, such as we can imagine belonging to the melancholy Trois Eschelles and the rollicking Petit André, the two hangmen in Quentin Durward. In the first the nasal opening is narrow and pointed, in the other broad and almost quadrilateral; in the former the jaw is narrow, the roof of the mouth highly vaulted, and the angle of the lower jaw more obtuse than

[1] This subject is discussed at length in a paper read before the Association of American Anatomists at Washington, May 30, 1894, which is to appear in the *Medical Record*.

in the other. But such typical faces are not very common. The characteristic points are usually wanting in clearness. Not rarely they are even transposed, so that for instance a short face may have the lower jaw with the angle of a broad one, and vice versa.[1]

Often when overcome by the intense weariness of a Faculty meeting, I have sought relief in asking myself which of my colleagues I should be able to recognize were their nicely macerated skulls set on the table before me. There are striking types of heads in that august assembly, but I am convinced that the skulls I could swear to would be very few. Even so characteristic a countenance as that of the sad-eyed Mongolian is not, when reduced to a skull, so strikingly evident that one will readily pick it out from a number. Most of the characteristics of a head and face, the size being excepted, are in the soft parts.

The problem may present itself in various ways. Supposing that we had the skulls of two known persons before us, the identification should in most cases present no insuperable difficulty. In many cases we could declare with absolute confidence that a certain skull could not have belonged to a certain person. But while I do not question that the careful and minute study of an expert can accomplish much, I am anxious to insist that the identification of a skull from our remembrance of a dead person, even with the assistance of photographs, is in most cases no easy task.

As for the rest of the body, it cannot be denied that our results are more negative than positive. The shoulder-blade is a very variable bone. I do not know what range of variation a great series of the scapulæ of the larger felidæ might present, but a small one shows nothing like that of the human race, I might add even that of the Caucasian. Yet I am quite unable to find any connection between its

[1] Formen des Ober und Unterkiefers bei den Europæern. Dr. J. Kollmann. Schweizerischen Vierteljahrsschrift fur Zahnheilkunde, 1892.

shape and the contour of the shoulders. The length, breadth, inclination and shape of the acromion are all valueless. Perhaps the only deduction that seems clear is that the leverage required by a long arm calls for a long scapula.

Conversely, however, I may say, that heavy shoulders indicate large humeri. In the strongest arm bones the spiral formation is particularly developed. I have often seen in this type a large, prominent, external supracondyloid ridge suggesting that of the gorilla. I have never seen this ridge strongly developed on a weak or on a female humerus.

The variations in the details of the femur are endless. I have been baffled in trying to find any definite connection between the figure and the various features of the thigh bone, such as length, or angle of neck, its forward inclination, and indeed the general characteristics of the shaft. I have been inclined to associate the length and forward inclination of the neck with a well marked lumbar curve, but have no evidence that can be called convincing. Two peculiar shapes of the thigh bone have of late received particular attention, one of which, called the pilastered femur, characterized by the prominent posterior ridge and usually strongly bent, is associated with a very narrow tibia. While I have often found this association, it is not invariable, neither does it always imply large muscular development. The other is the flattened femur, which, except for its greater length, suggests that of the gorilla. I have found it generally in very powerfully built men. I have frequently seen the bending back of the head of the tibia which, together with a facet at its lower anterior border, has in prehistoric skeletons been advanced as evidence that an upright position was not fully attained. The studies, however, of Mr. Arthur Thomson, of Dr. R. Havelock Charles and of Monsieur Manouvrier have shown that it is rather to be considered as associated with powers of excessive

flexion, and perhaps with the habit of walking with bent knees. These peculiarities are seen in the leg bones of Orientals who sit squatted on the ground. Here is a Chinese tibia which had the lower articular surface continued on to the front. It in no way implies in either case that the upright position cannot be assumed. I have frequently seen a lengthening of the articular surfaces of the head of the femur which is associated with these features, but I have found it independent of any of them. As to the thin tibia of prehistoric skeletons, we often find striking examples of it in the dissecting room.

To come to practical application, I do not believe that it is possible to predicate the shape of the bones from that of the body, nor *vice versa*, with any great certainty. Often we should fall into grievous error in attempting it. I have notes on two male subjects that were in the dissecting room at the same time, which I shall call A and B. A's height was 176.9 cm. (say 5 ft. 9½ in.). B was a mere trifle (6 mm.) taller, but with broader shoulders, broader hips and longer legs. My notes state that A was slender, thin, with a flat chest, rather long neck, thighs somewhat bent outward. B was of very powerful build, with square, thick shoulders, very deep chest, strong legs. B's shoulder-blade is the larger, but by no means strikingly so. Had I measured the arm bones I have little doubt that one factor of B's heavier shoulders would have been apparent. But the femurs were a surprise to me. Each is remarkably heavily made, and though of different types one would hesitate which to ascribe to the more powerful man. In A it approaches the pilastered form, in B it is broad and flat. Here again are some very interesting bones from a lightly made, almost puny blind boy of nineteen, who had spent nearly his whole life in an almshouse in a sedentary manner, yet they are distinctly strong bones. The humerus in particular presents a striking contrast to that of the female mill operative who seemed almost twice his size.

The Origin of Individual Peculiarities.

This carries us to the causation of peculiarities of structure. Manouvrier argues at great length that the very thin tibia comes from the great development of the tibialis posticus, and the pilastered femur from that of the cruræus, useful muscles for walking in a hard country and with bent knees. While I would be the last to question the tendency of the human body in common with all other organisms to adapt itself to its surroundings, I cannot regard such explanations as sufficient. Manouvrier mantains also that the third trochanter is associated with the action of the gluteus maximus. I have endeavored to show on a previous occasion that the theory which explains the shape of bone by mechanical strain is unsatisfactory. We find the third trochanter only in a certain proportion among savage races in which presumably every one lived pretty much the same life. We find remarkable instances of it in delicate bones which show no signs of great muscular development. Finally we find it in bones that are too young to admit of its having been pulled into prominence by the muscles of its possessor. Manouvrier argues that the platycnemic tibia is due to the mode of life of the individual from the fact that it is not found in childhood. This does not follow. At early adolescence many changes take place in the framework of the body, then beginning to assume its final shape, which can be accounted for by no mechanical cause. Such are the development of the nose and of the larynx at the time when, to quote Thackeray, the boy's voice ranges from an unearthly treble to a præternatural base. Moreover, we are not now concerned with the question how great races acquired their charateristics, but whether mechanical explanations will account for the individual peculiarities found among us. Here we see every variety of shape of femur and tibia, to say nothing of shoulder blades. Here are pre-

historic forms occurring in the midst of us. Here are the strongly developed bones of the blind boy who did nothing. I have spoken of the wonderful variability of the human scapula. There is every reason to believe that it acquires its permanent peculiarities at a very early period. Macalister has found characteristic differences in the acromion at from two to four years, and I have two tracings of the outline of peculiar shoulder blades made for me by Dr. Monks from two sisters, aged seven and ten. The resemblance of these two tracings and the early development of outline is strong evidence that this depends upon other than mechanical causes. Without questioning that external influences can and do modify the shape, I am convinced that the main characteristics of each body are largely hereditary and are predetermined from the very beginning of development.

The Significance of Anomalies.

I have met with most of the recognized anomalies of the skeleton, and with some of great rarity. Large third trochanters, supra-condyloid processes, supra-troclear perforations, I have seen galore. Here is a large para-mastoid process of the occipital bone, which is found in many mammals, especially in the herbivora and rodents; here is a sternum with the manubrium reaching to the third rib, as is found in gibbons; here is the fossa prænasalis, best developed in the seal tribe.

Our collection of anomalous spines shows many curious forms. It is claimed that man is about to lose one of his 24 præ-sacral vertebræ. I have specimens showing the sacrum encroaching on the lumbar region, transforming the vertebra above it into a transitional one and reducing to sixteen the thoracic and lumbar vertebræ, it may be at the expense of one region or of the other. I have instances of the reduction of the thoracic vertebræ to

eleven without any remarkable disturbance in any region. There are, on the other hand, cases of increase of the præsacral vertebræ. There may be twelve thoracic and six lumbars or thirteen thoracic and five lumbars. Here are cervical ribs of various degrees of development. This is a bicipital rib recalling the condition in some whale-bone whales. Here finally on a spine showing cervical ribs and the suppression of a thoracic vertebra, is an absolutely unique case of absence of the anterior arch of the atlas.

Much do we hear of atavism. Every anomaly is forced to represent something animal, a short spine is that of the orang, a long one that of the gibbon, one anomaly recalls the sloth, another the seal, another a ruminant, another a marsupial. In the muscular system we have been carried back both to birds and to snakes.

We cannot have inherited the fossa-prænasalis from the seal. If it be inherited at all it must be from some common ancestor. Following this line of reasoning, we find that if all animal resemblances are reversions, the primitive ancestor must have been a very curiosity shop of peculiarities, in direct defiance of that principle of evolution which brings from the simple the more complex. Convinced as I am that every bodily difference between man and non-rational animals is of degree and not of kind, I am astonished and perplexed by the great net-work of analogies extending throughout nature. No one can ignore them without wilfully shutting his eyes. But the very multiplicity of these resemblances assures me that some other law than that of heredity must be invoked to account for them. They cannot be represented by a tree-like figure. They spread out every way. The opinion is growing daily stronger, among serious scholars, that if man's body came from a lower form it was not by a long process of minute modifications, but by some sudden, or comparatively sudden, transition. The fabulous missing-link, once so accurately

described by Hæckel, is retreating to the limbo of worn out hypotheses.

The Vital Principle.

The phenomena of growth show unmistakable evidence of an immanent force presiding over the development of the living organism, essentially different from the forces of non-living matter. Its action is strikingly shown in anomalies; not, indeed, in their production, but in remedying the evil. If, for instance, there be but eleven thoracic vertebræ in a spine, it is impossible to say which one is wanting, for a slight modification is found to have taken place in several by which the symmetrical development of the spine is maintained. In the unique case of total absence of the anterior arch of the atlas, a strong ligament running from the odontoid to each lateral mass holds the bone securely and yet allows movement. By what purely mechanical process can this wonderful adaption have been brought about? One of the characteristics of living matter is that its growth is directed to the perfection of the organism as one whole, not as a collection of independent particles. This is the action of the vital principle, which science can no longer afford to ignore.