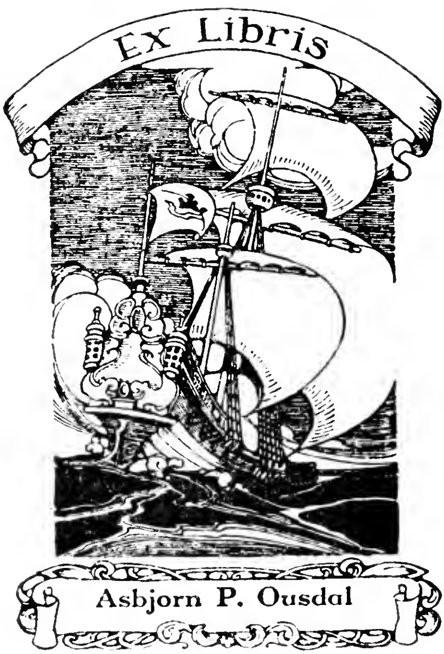
A LABORATORY MANUAL OF ANTHROPOMETRY

WILDER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BY

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WITH 43 ILLUSTRATIONS

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PREFACE

It has long been a reproach to American science that now, for many years, the branch of Physical Anthropology has been so little cultivated, and this the more because of our early prestige in this very field and because of our unrivalled opportunities.

When Morton, in 1839, published his Crania Americana, and followed this in 1844 by a similar work, the Crania Aegyptiaca, he gave the United States a leading place in the then new science of Craniology, but now after eighty years, in this and in related fields, American names are as rare in bibliographies as American merchant ships have been until recently upon the high seas. With the vast possibilities for ethnological study furnished by our aborigines, with the importation in the past of large numbers of negroes from Africa, which are now numbered by millions, and with the hordes of alien peoples from all parts of the world, who seek a foothold in the still new continent, not even Rome herself, in Imperial times, could supply such enormous ethnological material, yet the advantages taken of such opportunities have been but slight. Every large European power, and at least one Asiatic one (Japan), has surpassed the United States in Anthropometric work. In this line of Anthropometry, or Biometric Ethnology, especially, unheeded by and almost unknown to, American science, a great body of facts has been compiled in Europe, the facts being obtained by means of European instruments, collected by means of European technical methods, and rendered significant by means of European scholarship.

Some twenty years ago the growing need of unifying the technical measurements, at least those most commonly employed, became more and more apparent, and led to the adoption of a set of prescriptions governing the more important measurements of the skull, and of the head and facial features in the living. This was established at the meeting of 1906 of the International Congress of Anthropologists, held at Monaco, and the Committee consisted of representatives of France, Germany, Switzerland and Italy, but neither England nor America. The official report was in French by the Secretary, M. Papillault, and was published in the periodical *L'Anthropologie.* The movement towards a standardization of measurements excited a continually increasing interest, and its next official manifestation came at the Congress of the same body in 1912, meeting at Geneva. The Committee which prepared this report was a larger one (24 members), and included, beside the countries represented at the former one, Spain, Russia, Great Britain, Russian Poland, Hungary and the United States. This second report consisted of standardized measurements of the living body, exclusive of the head and face, which had been treated in 1906, and was published officially in three languages, French, German, and English. The three official recorders, appointed by the Committee to transcribe these prescriptions were, respectively, Rivêt, Schlaginhaufen, and Duckworth, and these three reports, made to correspond in meaning as closely as possible, were published in France, Germany, and England. For the benefit of the United States Dr. George Grant MacCurdy, one of the two American representatives on the Committee, published the same report, translated from Dr. Rivêt's personal copy, in two American periodicals, *Science* and the *American Anthropologist*, both during 1912, and the same thing was done in other countries and languages, *e.g.*, Frassetto's Italian version in the *Rivista di Antropologia*.

It was with a view to directing a broader American attention to this vitally important branch of Anthropology that the present author, sometime previous to 1912, drew up, based largely upon the prescription of 1906, a set of rules for the guidance of the laboratory student, principally along the line of craniometry, and this manuscript was worked over by his advanced students and himself, accompanying the actual measurement of skulls. The appearance of the second set of rules, the prescription of 1912, enabled him to add the authoritative rules for the principal measurements of the living body. Thus the work, tested in the laboratory by practical application, assumed somewhere near its present form.

The granting of a Sabbatical leave in 1913 by the Trustees of Smith College enabled the author to visit several of the European laboratories, where he had the opportunity of inspecting the practical anthropometric work carried on by some of the leading investigators in this field. He here takes this opportunity of expressing his sincere thanks to them all, who, in the midst of a busy term, found time to demonstrate to him their equipment and especially their personal technical methods by actual measurements. These include Prof. Fabio Frassetto in Bologna, Prof. Otto Schlaginhaufen, the pupil and successor of Prof. Rudolf Martin in Zürich, and especially Prof. Eugen Fischer in Freiburg in Breisgau, in whose anthropological laboratory he spent several weeks.

In 1914 appeared the long-awaited book of Prof. Martin, the "Lehrbuch der Anthropologie," only a few months before the bursting of the storm-cloud of a well-nigh universal World War, since which communication between the anthropologists of the two hemispheres became, for four years, all but interrupted. At best, however, this exhaustive textbook as it is large and expensive, and in the German language, is more or less impractical for the average American student, and while of the greatest value to specialists, it does not fill the needs of American Colleges and Universities, at least so far as undergraduates are concerned. These conditions caused the decision to publish the present volume, which has again been thoroughly revised, and is now offered in a somewhat simplified form. It consists primarily of the rules for measurements given in the two prescriptions of 1906 and 1912, and adds for the convenience of the student certain of the most useful indices. An enumeration of instruments, as employed in various places, is given in the introduction, together with a much simplified account of the most generally used mathematical methods employed in tabulating and expressing the results of measurements, for the especial benefit of that large class of students who find their chief interest in the morphological relations of the subjects treated, but whose mathematical ability is not great, and who are not able readily to follow the more abstruse methods and expositions of them made use of by biometricians.

The student is introduced to the bibliography of the subject by a series of footnotes, which are found under each heading, and are intended to guide him to certain of the most important papers, generally the ones especially followed in this book. From the bibliographies given here, in their turn, a more complete knowledge of the literature may be obtained.

The main work is followed by two appendices, the one (*A*) giving the actual measurements of 93 skulls and skull fragments of Indians from Southern New England, the other (*B*) the bodily proportions of 100 Smith College Students, both sets of measurements the result of work carried out in the Smith College Anthropological Laboratory by graduate students. These may prove useful as samples of the kind of work treated in this manual, and will be of interest to use in comparison with the results of the practical reader.

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

INTRODUCTION

THE HISTORICAL DEVELOPMENT OF THE SCIENCE OF ANTHROPOMETRY

When White in 1794, basing his assertions upon the observation of both skeletons and living men, made the statement that the forearm of negroes, in proportion to the upper arm, was longer than in white men, he inaugurated the science of Comparative Racial Anthropometry, and showed that there were constant differences in the bodily proportions of the various human races. Differences of this sort seem to have been unrecognized before this, even by artists and sculptors, who, although from the time of the Egyptian and Assyrian carvings had elaborated and even emphasized the racial characters of face and head, had given no heed to differences in the other parts of the body. It is thus quite possible that the classic sculptors of Greece and Rome may have used indifferently as models their own people and their foreign slaves, which may serve to verify and explain the asserted negroid proportions of the Apollo Belvidere.*

The assertion of White was an advance upon new ground, and although it was accompanied by neither detailed measurements, calculation of averages, or indices, it was yet of great value in the development of the subject. After this, however, the work rested for forty-four years, when Humphrey, in 1838, made careful measurements, not only of humerus and radius, but of femur and tibia also, in twenty-five skeletons of negroes and the same number of those of white men. He compared each individual length with the total height of the skeleton from which it came, taken as 100, and thus obtained *indices* which could be directly compared. His results corroborated White regarding the long forearm (radius) of negroes, and found a similar greater length in the lower leg (tibia) of the same race, as compared with the whites. He found, for example, that the average humerus in the two races bore practically the same proportion to the total height, 19.52% in negroes and 19.54% in whites, while the figures for the radius, also expressed in a percentage of the total height, were respectively 15.16% and 14.15%. In the same way the figures for the femur were 27.40 and 27.51, a negligible difference, while those for the tibia were 23.23 and 22.15.

But by this time other anthropologists had become interested in racial differences in bodily proportion, and under the critical scrutiny of Broca this subject received still more careful treatment. He pointed

* Perhaps a Greek head on a negro body, as has often been asserted.

out the fact that a total height obtained from an articulated skeleton depended too much upon the preparator who put the bones together, and hence disregarded this uncertain measurement in favor of one involving the length of a single long bone, or of two combined. He thus substituted for Humphrey's standard, now the length of the femur, now that of the radius, or again the combined lengths of humerus and radius or femur and tibia, with each of which, in turn, with a value of 100, the lengths of the other long arm and leg bones was compared.

The next great advance in treating the general subject of racial anthropometry was the realization of the fact that many of the bones could be measured practically as well in the living subject by ascertaining the precise location of their termini by palpation; also that certain integumental landmarks, not associated with the skeleton, such as the umbilicus and the nipples, were of considerable value in the study of proportions. This line of work, the anthropometry of the living subject, developed naturally in the field, as osteometry had developed in the museum, and was the direct result of the series of great scientific voyages, like those of the *Novara* and the *Challenger*, characteristic of the last third of the Nineteenth Century. Naturally in the development of physical ethnology the facial features had long received much attention, and had become the subject of careful measurements, with averages and indices, and the extension of this work to the rest of the body naturally followed.

During this epoch, in 1882, to be precise, a young anthropologist, M. Alphonse Bertillon, noticing the individual character of bodily measurements, saw in them important data for the solution of the many difficulties which, up to this time, confronted the Judicial arm of the French Government, that of establishing the individual identity of criminals, and inaugurated the famous system of "Bertillonage," based upon eleven easily taken measurements, a system that has now for many years yielded the most satisfactory results, and is still in general us , although now being rapidly replaced by the Finger-print System of Galton and Henry.*

The investigators of this period began by measuring the distances between landmarks directly, that is, the lengths of the long bones from end to end, as had been previously done with the shorter distances of the head and face, but it was soon seen that if the subject were standing erect, with heels together, in military position, it was necessary only to ascertain the distance from the floor of each terminus, and obtain the various required lengths by subtraction of one height from another, thus sparing time to both subject and operator in the work of measuring, at best a tedious process. This was naturally possible only when arms and legs were held "straight," *i.e.*, perpendicular to the floor, so that it is always necessary for the subject to stand as erect as he can. Aside from

* Wilder and Wentworth: "Personal Identification." Badger, Boston, 1918.

limb measurements, the same subtraction methods may be conveniently used in ascertaining the difference in level between any two landmarks, whether median or lateral; thus, between nipples and umbilicus, or between the incisural notch in the front of the neck and the iliac crest. The distance thus ascertained is that between the two horizontal planes passing through the landmarks in question, and thus all measurements made in this way may be regarded as *projections*, or the point where horizontal planes passing through the points measured strike an imaginary line erected vertically, perpendicular to the floor.

Thus by the opening of the New Century anthropometry had already become an important branch of anthropology, expressed in extensive and rapidly increasing literature. Individual investigators, however, differed widely, not only in the measurements employed, and in their relative value, but in the manner in which these measurements were taken and the instruments used, so that there could be little or no trustworthy comparison between the results of different investigators. The ciencse was thus ready for its next phase of development, the standardizing of the measurements. This was first attempted in the case of the skull, as craniometry had received the most attention and its measurements were thus the most in need of standardizing, and came as the result of the International Congress of Anthropologists meeting in Monaco during April, 1906. The proposal for this came from the Committee of the Congress, MM. Hamy, Papillault, and Verneau, and the work was done by a special committee appointed for the purpose, MM. Giuffrida-Ruggeri, Hamy, Hervé, Lissauer, v. Luschan, Papillault, Pittard, Pozzi, Sergi, Verneau, Waldeyer. The proposals presented by the Committee (38 for the skull, and 19 for the living head and face) were ratified by the Congress, and have thus become the set of standard skull measurements, to be followed, so far as possible, by anthropometrists everywhere.

A second standardization, that of measurements of the living body, excluding the head, resulted in much the same way, from proposals ade at the International Congress of 1912, which met at Geneva, Switzerland, in September of that year.

The Committee consisted of 23 members, as follows: MM. Czekanowski, Duckworth, Frasetto, Giuffrida-Ruggeri, Godin, Hillebrand, De Hoyos, Hrdlička, Loth, v. Luschan, MacCurdy, Manouvrier, Marret, Mayet, Mochi, Musgrove, Pittard, Rivet, Schlaginhaufen, G. Sergi, Sollas, Volkov, Weissgerber. The increased interest in anthropometry is shown in the larger size of the Committee as compared with that of 1906, and the spread of this interest to other countries is indicated by the inclusion in it of representatives from England, Russia, Switzerland, Spain, Hungary, and the United States (Hrdlička and MacCurdy). There were 49 separate measurements proposed by the Committee, and these were, as in the previous case, unanimously voted by the Congress.

The anthropometry of the bones of the skeleton, aside from the skull, has not as yet become subject to International Agreement, and is thus still in the stage of craniometry just previous to 1906, that is, detailed measurements have been worked out for the separate bones by different investigators, but the work needs yet to be standardized and those measurements selected which are generally considered essential.

If we except the pioneer work of Turner, who published his work on the skeletons collected by the Challenger Expedition in 1886, the detailed osteometry of the separate bones has been the work of the Twentieth Century. The *femur*, naturally the first bone to receive special attention, was first adequately measured, according to modern methods, by Lehmann-Nitsche in 1895, who included also some details of the *tibia;* but the first thorough osteometric treatment of *ulna* and *radius* was delayed until 1906, when it was presented by Fischer in a paper which may well serve as a model for similar work. The *pelvic girdle,* with details of the *ossa coxæ* (*ossa innominata*), was well worked out in 1900 by Koganei and Osawa, but for the completion of the bones of this immediate region the world waited until Radlauer's work on the *sacrum* in 1908. The modern treatment of the *vertebral column,* a difficult problem for the osteometrist, was delayed until 1912, when it received competent treatment by Hasebe. The skeleton of *hand* and *foot* may be treated as a whole; or certain significant bones, especially those of *carpus* and *tarsus* may be considered by themselves. Thus, for the foot skeleton as a whole, there is the paper of Volkov in 1905, and that of M. and Mme. Adachi of the same year; while for separate foot bones those of Sewell (1904–1906) on the *talus,* of Manners-Smith on *cuboid* and *naviculare* (1907), and of Reicher on the *calcaneus* (1913) may serve as examples.

It may thus be said that, at the outbreak of the European War, in 1914, the field of osteometry had just been covered as far as the first blocking out of essential measurements for the separate bones, but that no attempt has been made to establish a general agreement or to insure universality in usage; still less has there been a sufficient number of studies based upon the bones of the separate human races to form the basis for much comparison. It is at this point that we may trust the work will be resumed at the expiration of the Great War.

The employment of *angular measurements,* now an important part of anthropometry, especially in the case of the bones, has had a course of development closely similar to that of the linear measurements above reviewed. The first angle employed was the famous "Facial Angle" of Petrus Camper, described in a posthumous work of this author, bearing the date of 1780. This angle was drawn upon the lateral aspect (profile) of skulls and living heads indifferently, and was that formed between a line passing through the base of the nose and the auditory meatus, and one roughly tangential to the profile. Camper found this angle to average 70° in Negroes, 80° in Europeans, 90° in classical Greek statues delineating mortals, and 100° in certain of their representations of gods. On the other hand the apes, monkeys, and lower mammals gave angles less than 70°, in a decreasing series, so that this facial angle was roughly a measure of the height of the forehead and hence indicative of the general intelligence.

As with linear measurements, the Mid-Nineteenth Century, largely under the leadership of Paul Broca, brought into use other angles, for the most part those of the skull, while at the present times important angular measurements have been established for many other bones. Aside from single angles some anthropometrists make use of triangles, quadrilaterals, and even higher polygons, mainly in connection with mathematically drawn projections of bones upon a plane surface.

With the living body, in spite of the fact that the first angle used, that of Camper, found here its main application, there are now few, if any, angles in common anthropometric use, although certain ones mainly those associated with the arm, leg, or foot, have a pathological or orthopedic significance.

No International Congress has as yet attempted to establish or define any prescribed angles for either the bones or the living body, and the matter rests at present, as was the case with linear measurements previous to 1906, with the individual investigators; certain obvious angles are commonly employed, and with considerable uniformity in definition, while others are devised by individual authors and used in bringing out relationships the value of which has not as yet been thoroughly tested. A distinct advantage of an angle over a linear measurement lies in the fact that angles may be compared directly in individuals of different size, and need no index; possible disadvantages are found in the uncertainty of fixing the lines which describe them, and in the difficulty of reading them accurately.

Concerning the actual value of anthropometric measurements, of whatever sort, and the extent to which measurement may be profitably carried, both opinion and practice differ widely. As in other forms of biometrics, where mathematics plays an important part in the investigation of a primarily biological problem, certain investigators are bound to be more interested in the mathematical than in the biological side, and there is always danger that, in their hands, the latter cause may suffer, and the work be viewed as a mathematical problem, in which the goal is reached when the new relations involved are expressed in the form of formulæ and tables. Others, on the other hand, view Physical Anthropology as wholly morphological, and place their reliance upon forms and form-comparisons as revealed to the eye, being very wary about expressing any character in a mathematical form.

As an example of the mathematical extreme, of an anthropometrist in whose hands the whole subject becomes an endless series of measurements, we may take the Hungarian investigator, Dr. Aurel von Török, who, in his extensive text-book of Craniometry (Grundzüge einer systematischen Kraniometrie, Stuttgart, 1890) enumerates for the skull alone no fewer than 5371 linear measurements and projections, together with a proportionate number of indices, and many hundreds of angles, triangles, polygons, etc. To him the goal of the anthropometrist appears to be in part to make so complete a mathematical mensuration of a given skull that it could be faithfully reproduced if destroyed, but in great part also to seek every possible way in which such an object may be measured. Is it any wonder that to him the complete and satisfactory measurement of a single skull is a sufficient subject for a Doctor's thesis?

Quite the opposite view is that of the veteran Roman anthropologist, Giuseppe Sergi, who urges the study of varying shapes by the method usually employed by the zoologist and anatomist, that is, mainly by the eye. In commenting, for instance, upon the sorting out of European head types by the length-breadth indices of the cranium, a very obvious and elementary sort of anthropometry, he asks how many species of lark we should get if the ornithologist should attempt to separate them by the ingenious method of measuring the total length from tip of beak to tail and divide this by the wing-spread. He counsels the application of what he calls the "zoölogical" rather than the anthropometric method to the study of racial skulls, and thinks that one should learn to distinguish them by characters that one can perceive without measurement. "As a zoologist can recognize the character of an animal species or variety belonging to any region of the globe or any period of time, so also should an anthropologist if he follows the same method of investigating the morphological characters of the skull."*

It seems plain that somewhere in the wide range between these two extremes there is the legitimate place for a rational anthropometry, an anthropometry that employs mathematical methods in the definite expression of morphological relationships, and devises various methods of measurement to bring out differences already perceptible to the eye of the trained observer. As the most prominent exponent of this form of the science, whose goal is ever the detailed observation and comparison of the various representatives of man and man's allies at present and in the past, and who employs the technique of anthropometry most successfully in the pursuit of this goal, we have the great anthropologist of the University of Strassburg, the late Gustav Schwalbe, and the beginning anthropometrist can do no better than study any of the classical papers produced by this man during the last twenty years of his life (1896–1916) in order to gain a clear idea of the great service of measurements as a handmaid to morphology. In the field of comparative human evolution, in the comparison of modern human types with the various prehistoric forms, he has used the data gained from indices and angles to

* SERGI, G.: The Mediterranean race, *Scribner's*, 1901, p. 36.

the best advantage, and during this investigation, endeavoring constantly to bring out real morphological differences, has established certain measurements which now rank among the most important and universally employed of anthropometric data.

Aside from Schwalbe, who was very conservative in his use of measurements, there is a large school of anthropologists of moderate ideas, who seek to describe the bones of representatives of the various races, and their bodies as well, by making a reasonable number of measurements, and at present in the special measurements selected there is in general a close agreement. Actual conditions may be represented by a comparison of the work of several of the leading investigators in regard to craniometry, or the application of measurements to the description of the skull. In 1906 Frédéric, an associate of Schwalbe, described certain individual skulls by the help of 53 separate data, of which 26 are linear measurements; 17, indices; 5, angles; and 3, girths. Adachi, in 1904, in a paper specially devoted to the examination of the orbital region of Japanese skulls, employs 56 separate data, of which the greater number refer to the orbit proper. E. Fischer (University of Freiburg, 1913) presents in his laboratory outlines, for skull mensuration, which he furnishes to his students, a list of 77 separate data, 43 of which are linear measurements, 3 are angles, 8 are girths, and 22 are indices; and Schlaginhaufen (University of Zürich, 1913) uses for the same purpose 82, for the most part identical with the former. Even v. Török, with his extreme views regarding possible craniometrical measures, is yet willing to print a list of what he calls the "most important" data, which he considers sufficient for purposes of general description, and which include only 26 linear measures, 8 indices, 3 girths, and a few other data, 39 in all. Duckworth (University of Cambridge, England, 1910) employs in a descriptive paper on Sardinian crania no more than 11 measurements and 5 indices, although he recommends in practical laboratory work (1904) 15 linear measurements, 7 indices, 3 angles, and the cranial capacity. Finally the Prescription of 1906, which obtained the unanimous approval of the International Anthropological Congress, comprises 38 separate data: viz.,—32 linear measurements, 3 arcs, 1 angle, and the cranial capacity.

A real danger that besets the anthropometrist along the mathematical side, and one to which a student may be naturally brought by seeking to be accurate, is the temptation to treat with too great respect the actual figures obtained from the individual measurements, to regard the decimal places as of equal importance in all cases, and to feel that a series of measurements carried out to the third place, for instance, is much more accurate and reliable than one carried out only a single place beyond the point.

As a matter of fact, the accuracy of a result depends essentially upon the method of making the measurement, and here not only must the personal equation, as involved in the operator, be taken into consideration, but also the condition of the material measured, for where the decimal places used go beyond the error of two consecutive measurements, there is absolutely no value in carrying them out. If, as an illustration, we find that in a certain skull measurement, the results obtained by different operators, or by the same operator at different times, do not agree with each other to within 0.5 mm., it is simply time lost to attempt to carry out the individual measurements beyond one decimal place. Especially in the case of measurements of the living, where the operator has to consider, not only his own degree of accuracy, but also the slight involuntary changes of position of the subject, there are certain of the longer measurements where one cannot hope to be accurate within a whole centimeter, and where attention to differences of 2–3 millimeters would be of no possible avail.

ANTHROPOMETRIC INSTRUMENTS

The instruments employed in anthropometry may be grouped according to form and use, as follows:

- I. Instruments for measurement
  - 1. Linear measurement
    - calipers
      - craniometer
      - pelvimeter
    - slide compass
    - anthropometer
    - rod compass
    - osteometric board
  - 2. Girths and arcs
    - tape-measures
  - 3. Angles
    - goniometer (stationary)
    - goniometer (for attachment)
    - special types of goniometer
  - 4. Torsion (shaft of long bones)
    - parallelograph
  - 5. Volumetric instruments
  - 6. Scales for recording weight
- II. Instruments for holding and orienting skulls and other bones
  - simple types of craniophore
  - cubic craniophore of Martin
  - osteophores
  - combined craniophore and osteophore of Wetzel
- III. Instruments for drawing and delineating
  - dioptograph of Lucae
  - perigraph of Lissauer
  - diagraph of Martin
  - stereograph of Broca

I. Instruments for Measurement

The two most convenient types of instrument for measuring linear distances as defined by two points forming their termini are:

1. Calipers (Fr. compas d'épaisseur; Ger. Tasterzirkel)
2. Slide compass (Fr. compas glissière; Ger. Gleitzirkel)

These two types (Fig. 1) differ most widely in the shape of their legs, which in the first are long and curved outwards, to admit of passing around an awkwardly shaped object, and in the second are short and generally straight. Both consist essentially of a metric scale, to one end of which one leg is immovably fixed, while the second leg slides back and forth along the scale, but in the caliper form the legs spread apart from each other upon a pivot placed at a distance from the scale, while in the slide compass the two legs are constantly parallel to each other.

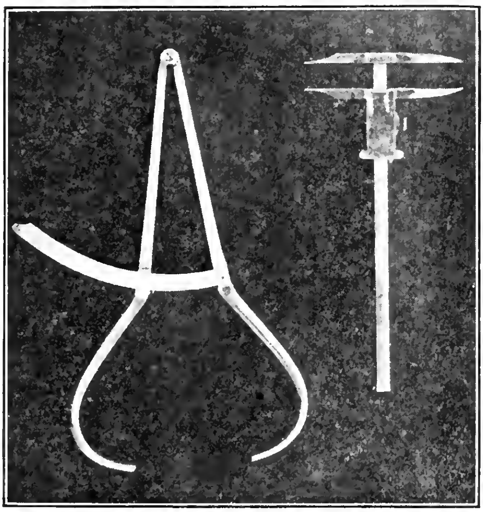

FIG. 1. —Two common instruments. (*Made by Hermann, Zürich.*)
(The one on the left) Calipers [Fr. compas d'épaisseur; Ger. Tasterzirkel.]
(The one on the right) Slide compass [Fr. compas glissière; Ger. Gleitzirkel.]

Calipers.—There are two forms of *calipers* with reference to the shape of the measuring scale; (*a*) the Bertillon form (Fig. 2), with the scale made on a curve, and sliding in an immovable slot upon the movable leg, and (*b*) the form in which the scale is straight and runs in a separate piece, attached to the movable leg by a pivot (Fig. 1, left hand). Both types are furnished with a binding-screw, which, by fastening the movable leg to the scale may fix a given measurement as long as needed.

It has been found convenient also to make calipers in two sizes, with varying capacity:

1. A smaller size, designed mainly for the measurement of heads and skulls, and hence called a *Craniometer*. Its scale measures 250 mm.

2. A larger size, designed primarily for taking of thoracic and pelvic

measurements in the living. It is called a *Pelvimeter*, and has a scale of 600 mm.

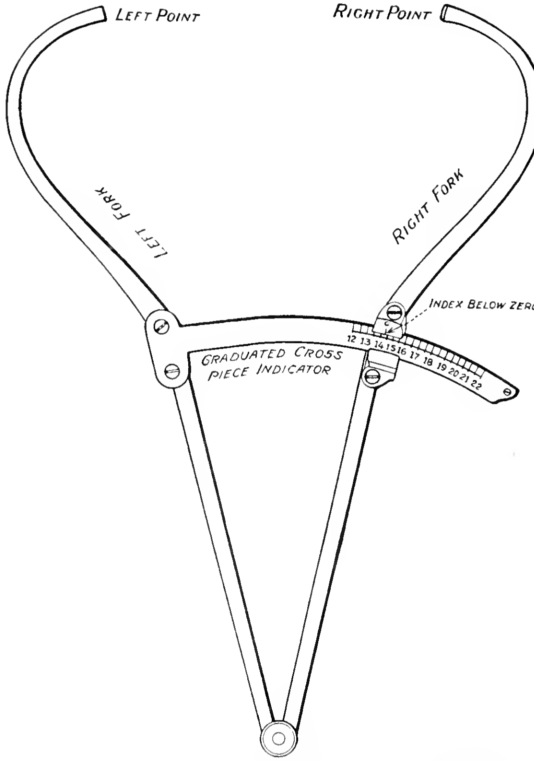

FIG. 2.—Bertillon's type of calipers. (*After Bertillon.*)

Slide Compass.—In the *slide compass* the scale rod is always straight, and forms the handle, upon which the movable leg slides, to record its distance from the fixed leg (Fig. 1, right hand). In the now more usual anthropometric form the legs project to an equal distance upon each side of the scale and end upon one side in sharp points, for use in the measurement of bones, and upon the other in rounded points, flattened horizontally, for taking the measurements of the living. Bertillon used two forms, a smaller and a larger, both differing in certain points from the one described and figured here. The smaller size possesses flanges along the sides of the legs, and the movable leg is shorter

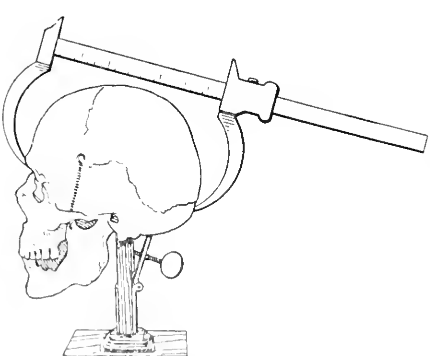

FIG. 3. Flower's type of calipers. (*After Duckworth.*)

than the other; in the larger type the legs project almost wholly upon one side.

These types, like the Bertillon form of craniometer, were originally designed to take only certain specific measurements, of use in the identification of criminals, and are still in general use for this purpose. They answer fairly well for general anthropometric purposes, but are not fitted for as general use as the other types. As another special form of slide compass may be mentioned Flower's craniometer, used by the English for purposes similar to those for which the smaller calipers are employed; it has the curved legs of calipers, but in design and plan is a slide compass (Fig. 3).

Anthropometer.—The anthropometer (Fig. 4), the most generally useful of all anthropometric instruments, is especially designed for use

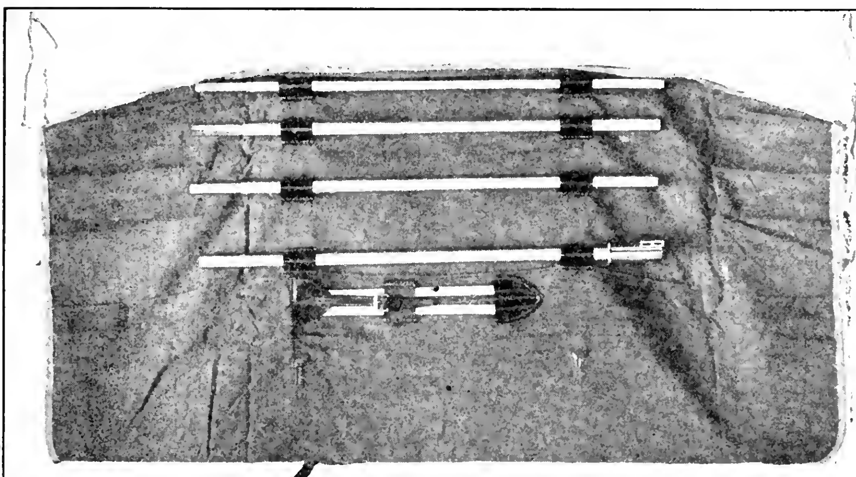

Fig. 4.—Anthropometer of Martin, in the folding linen case, ready to be taken into the field. (*Made by Hermann; Zürich.*)

in the field, and is thus capable of being readily unshipped and packed in a small folding canvass case. It consists essentially of a long rod of rigid steel, made of four separate lengths of 55 cm. each, which, when put together into one piece, has a length of two meters. Upon one side this rod is graduated in an *ascending* scale, from the free end, which is intended to rest upon the ground, up to the top, to which is attached an immovable socket (seen upon the top of the rod in Fig. 5). A similar socket, also intended to bear a cross-rod, slides freely up and down the rod, and registers the height from the ground of any point upon which the end of the cross-rod rests (in Fig. 5 the operator is recording the height of the head of the radius in the standing subject).

Upon the opposite side of the long upright rod, its two upper lengths bear a graduated ruling in a *descending* direction, with the zero point at the upper, immovable socket. Using these two upper lengths of the rod by themselves, and reversing the cross-rod in the movable socket, we have a large slide-compass.

The entire instrument is thus a double one; in one form of adjustment it is an *anthropometer*, used for determining the exact height above the ground of any given point upon a standing or sitting figure (living), and

FIG. 5.—Anthropometer, being used for ascertaining heights from floor.

by means of a few slight changes it becomes converted into a *rod-compass*, (*Stangenzirkel*) or large form of slide compass, with the legs composed of two long rods, which may be adjusted to varying lengths, and used for nearly all of the purposes for which the more specialized forms of craniometer, pelvimeter, and small slide compass are commonly employed.

Rod Compass.—In adjusting the instrument to these two uses there is necessary a difference in the insertion of the cross rods, as well as in the scale used and the method of reading their values; and while the proper methods for each use, with the various compensations to make the actual distance between the points of the two rods, or the exact height of the single rod, correspond to that indicated on the scale, a brief review of the rules to observe may not come amiss.

(*a*) To set up the instrument as an *anthropometer.*—Use all four lengths, so adjusted as to make a continuous scale of two full meters, divided into centimeters and millimeters. A single cross rod is necessary, and this is to be put into the movable socket, with the point prolonging the *lower* edge of the rod. The proper reading is indicated by a thin edge of metal, borne near the upper end of the socket on the side of the *ascending* scale.

(*b*) To set up the instrument as a *rod compass.*—Use the two upper lengths only of the main rod, but employ both cross rods. The upper one of these latter, borne by the fixed socket, should be placed with its point prolonging its *lower* edge; the lower one, borne by the movable socket, should have the point prolonging its *upper* edge; that is, the two cross rods, when placed together, should have the two points in contact. The *descending* scale should be used, and the reading is indicated by the flat upper surface of the movable socket. Note that the proper compensations are made at the beginning of the scale, where three millimeters are taken off.

Osteometric Board.—The *osteometric board* is used in taking the length of the long bones of the skeleton, and consists of a flat board,

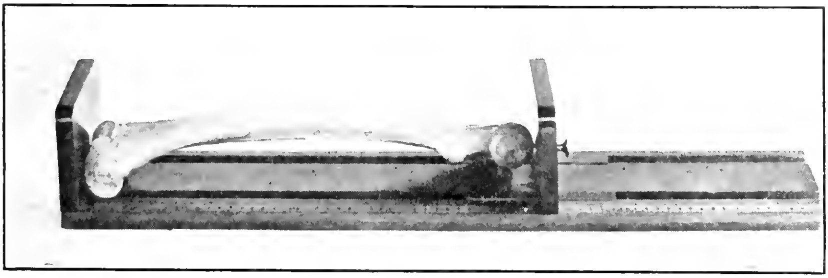

FIG. 6.—Osteometric board of Broca.

with an inlaid metric scale, and with a cross piece immovably attached at one end. A second cross piece, held always parallel to the latter, slides back and forth along the main board, and the bone to be measured is shut in between the two. The length is then read off on the scale.

Tape-measure.—For all measurements of girth, and also for certain arcs which present themselves on the surface of the head or skull, the wellknown *tape-measure*, graded to millimeters, is universally employed. The only question in the matter lies between the steel or the cloth form, and each possesses certain advantages. The steel remains unyielding, and is as good for use after years of employment as at first, while even the best weave of cloth stretches, often after a comparatively brief employment. On the other hand steel tape is necessarily rigid, and does not apply itself to a slightly wavy, or otherwise irregular, surface as does the cloth, and by spanning the hollows may give an incorrect reading, provided the perimeter of the actual surface is desired. On the whole it is to be recommended to employ cloth tapes, which are to be frequently renewed. It is also advisable to test all tapes in use at very frequent intervals, by applying them to some rigid measure, as the rod of the anthropometer.

Goniometer.—Frequently, when an investigator has found a certain angle, as shown generally in the skull or other bone, or perhaps in the living profile, he devises a special instrument (*goniometer*), designed to

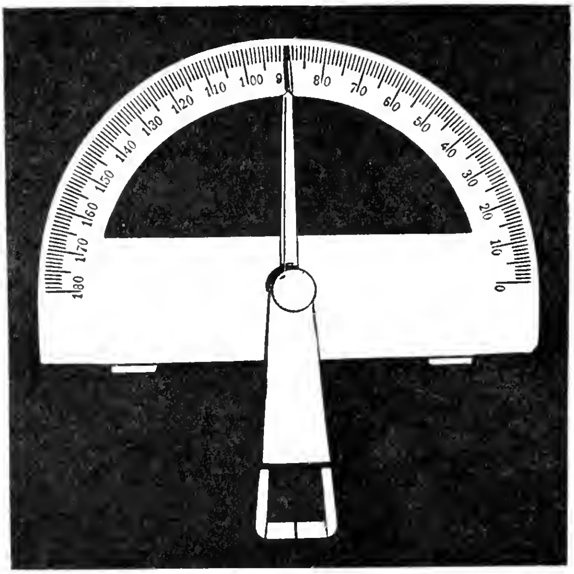

Fig. 7.—Attachable goniometer of Mollison. (*After Mollison.*)

record the measure of this special angle, and this practice has thus resulted in putting before the anthropologist a large number of such special instruments.

Goniometer of the "Clamp-on Type."—A generalized type of goniometer is found in the *Ansteckgoniometer*, or "*Clamp-on Goniometer*," of *Mollison*. This is made for attachment to other instrume ts and is thus capable of measuring almost any angle where the part under observation is immovable, as with a skull in a craniophore, since the instrument depends upon gravitation. It consists essentially (Fig. 7) of a protractor, to which is attached a swinging needle, with a heavy base. The frame of the protractor possesses a slot, controlled by a spring and binding screws, allowing an easy attachment to any one of several parts of the slide compass, or to other instruments, so that the angle formed by the line joining the end of the legs of the compass with the perpendicular, as defined by the swinging needle, which forms a plummet, may be readily ascertained. Thus, in a skull placed in the Frankfort horizontal the means are here at hand of determining the angle made by any surface, or by the line joining any two points, with either this horizontal or with a plane at right angles to it, such as the median sagittal, or any frontal plane.

The accompanying figures (Figs. 8 and 9) will give suggestions as to possible uses of this valuable little instrument, and no doubt others may be devised by the reader. In all cases it will be noted that the angle

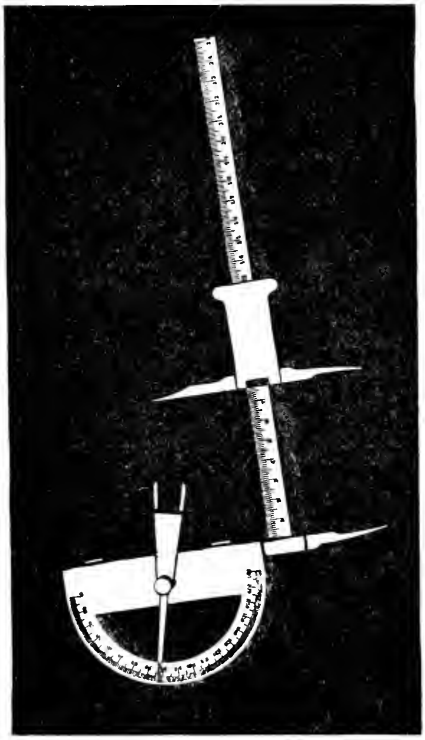

FIG. 8.—Attachable goniometer of Mollison used with the upper cross arm of the slide compass. (*After Mollison.*)

indicated is that formed by the line connecting the two ends of the legs of the compass with the vertical.

Stationary Goniometer.—A rather more special goniometer, especially designed for getting any of the angles involved in the profile of a skull, is the *stationary goniometer* (Fig. 10). This also is intended for use with a skull placed in the FH,* and must itself be accurately leveled, and used upon a horizontal table. For this purpose it is provided with leveling screws and spirit levels in two planes. It is essentially a slide compass,

* Frankfort Horizontal; this customary abbreviation for a constantly recurring phrase will be employed throughout this book, cf. below, p. 38.

and is thus provided with two sliding cross rods, graduated in millimeters; the upper rod is fixed, the lower movable. As the entire apparatus may be raised or lowered in its standard, the fixed upper rod can be readily placed at the upper limit of the line to be tested, while by moving the lower one up or down, and by pushing it in or out, its point may be adjusted to the lower terminus. This line is thus recorded upon the goniometer by the two points of the cross rods, and may be read off upon a protractor, by so placing the long needle that its lower thin edge exactly crosses on the lower rod the degree indicated upon the upper one by the little mark in the center.

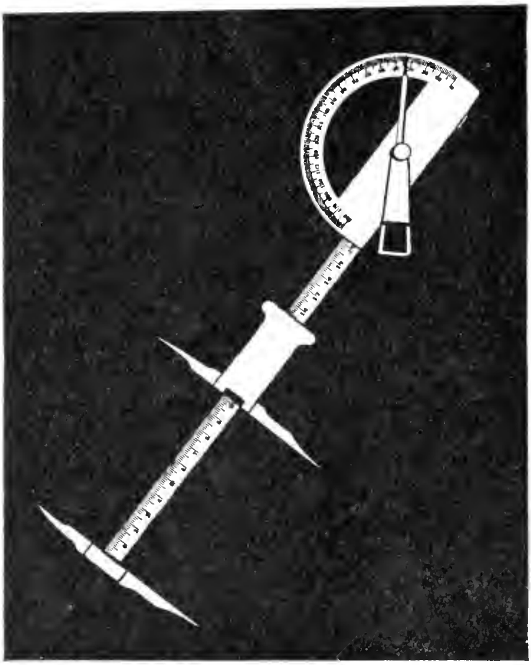

FIG. 9.—Attachable goniometer of Mollison used upon the scale rod. (*After Mollison.*)

Aside from this the upright standard of the instrument, which may be raised and lowered in a slot, is also graduated to millimeters and can thus record differences in level. With the graduating of the cross rods also, there are numerous other uses to which this instrument may be put aside from the measurement of profile angles. Yet, these other uses are generally as well performed, and more conveniently, by such simpler instruments as the clamp-on form of the goniometer, and thus the more complicated form is probably destined to be gradually superseded.

Parallelograph.—The *torsion*, or twist, in the shaft of a long bone, as shown by a superposition of the axes of certain features at its two ends, is a very special, yet often an extremely important, character. This is measured by the *parallelograph*, an instrument designed to record the projection of any given transverse axes established at the two ends, and projected upon a plane at right angles with the main axis of the bone (Fig. 11). If, for example, in the case of the femur, the axis of the head and neck be indicated by a knitting needle (A_1), fastened to the bone by wax or plastilina, and if at the other end the axis of the condyles be similarly shown by a needle placed tangent to the condyles upon their ventral surfaces (A_2), the torsion of this bone would be indicated by the

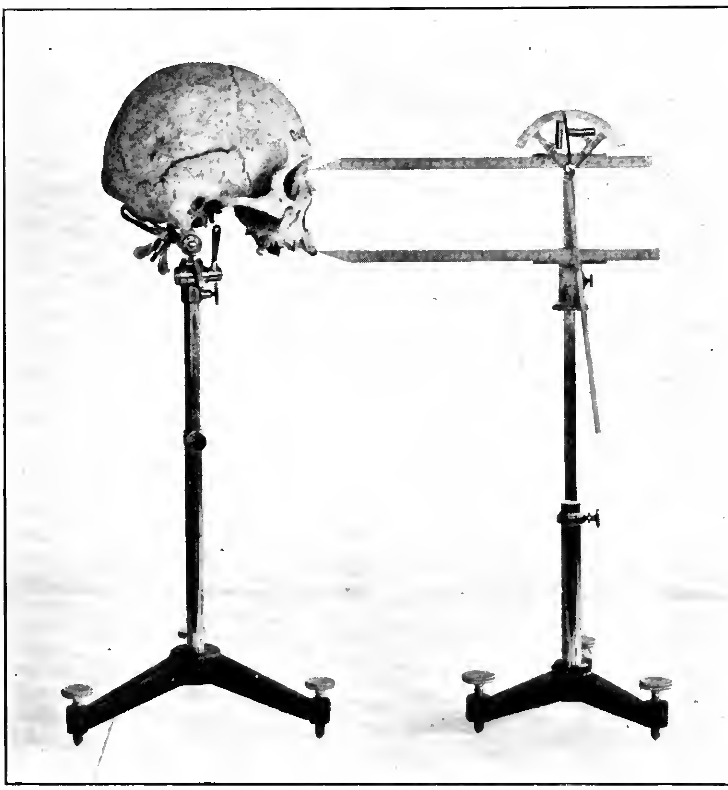

FIG. 10.—Stationary goniometer of Martin. (*Manufactured by Hermann; Zürich.*)

angle made by these two needles, when the bone is viewed "end on;" in other words, when these two axes are projected upon a plane perpendicular to the shaft. (For an illustration of this, cf. Fig. 32).

To actually draw and measure such an angle, a bone is taken, and the cross axes to be compared are indicated by the needles, after which the bone is placed in an osteophore, which holds it rigidly in a vertical position. A retort stand, equipped with a heavy iron clamp, capable of movement in several directions, serves as the osteophore. This apparatus, including the vertically placed bone with the two needles, is to be placed upon a large sheet of paper, so fastened as to prevent slipping.

The parallelograph, the function of which is to accurately delineate the position of the two needles, projected upon the paper, is essentially a diagraph, like the one described below, having two arms ending in points that can be placed, the one exactly above the other, so that, when the upper one touches a certain point the lower one pricks the paper exactly beneath it. When, now, two points upon each needle are thus recorded upon the sheet of paper, the position of each is fixed, and

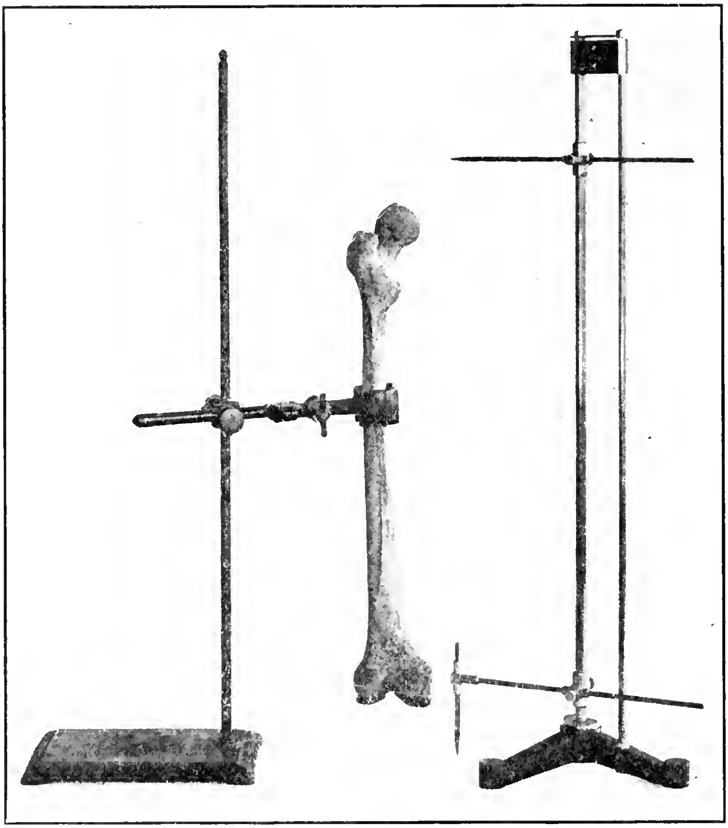

Fig. 11.—Parallelograph of Martin. (*Manufactured by Hermann; Zürich.*)

their projections are drawn by simply connecting the points of each line by means of a ruler. The angle is then measured by a protractor.

The parallelograph consists essentially of a vertical rod, rising from the center of an iron tripod, paralleled by a rod of smaller caliber, arising from one leg of the tripod base, and fixed immovably to the first at about 3 cm. distant. The larger rod bears two freely movable sockets, controlled by binding screws each bearing a horizontal steel needle, each of which may be pushed back and forth through its socket, also controlled by screws. As the needles are graduated the two can be pushed out to exactly the same length. When this is done the two are brought perfectly parallel by swinging them against the smaller of the two parallel uprights. The points of the two needles are now in the proper position the one exactly above the other, but are directed differently, for while the point of the upper needle is directed outwards, as the prolongation of the needle itself, that of the lower is carried upon a secondary piece at right angles to the main needle, and is thus directed downwards, so that it may prick the paper placed beneath the apparatus.

To project a given line (here a knitting needle fastened to the bone to be measured with respect to torsion) the point of the upper needle is placed in contact successively with two points on the needle defining the axis to be projected, while the lower needle records the points by making slight punctures in the paper beneath. If any two approximately transverse axes are both projected so that they cross, an angle is formed that can be easily read.

In using the parallelograph care must be taken that both transverse needles of the instrument are in contact with the smaller upright, and that they are pushed out equally; as otherwise the points would not lie in the same line vertically. This may be made certain by bringing the upper arm so far down towards the other, that the point of its needle coincides with the median axis of the vertical part of the lower needle. The shape of the upper end of this facilitates this comparison.

Volumes.—The principal *volumes* used by the anthropometrist are those of the *cranial cavity* and the *orbit of the eye*, the first one of the very earliest, the other one of the latest of anthropometric data to be developed. For the first, the technique for which is to be found elsewhere, the essential apparatus consists of some medium with which to fill the cavity, such as shot, sand, mustard seed, etc., a graduated cylinder in which to measure the medium, and usually some simple mechanical means to insure a uniformity in pressure during the filling and emptying.

A *control skull*, either an actual skull, or a receptacle of similar shape, of known capacity, is frequently used at short intervals during the work, to see that the measurements are made with a fair amount of uniformity.

Weight.—The *weight* of an object is seldom used in anthropometry except in the case of the entire body. The weight of certain organs in a perfectly fresh condition, as provided during an autopsy, has also been found of some value, especially in the case of the brain; but the weight of bones depends so much upon their condition, especially with regard to water content, that, except where the condition is absolutely the same, as in comparisons of the weight of the different bones of the same skeleton, such are of no especial value. For all such work any form of reliable scales provided with the metric weights is satisfactory, for accurate bodily weight special forms of scales are obtainable, as are used in gymnasiums, hospitals and clinics. To have any anthropometric value the weight of the unclothed body should be taken. (See below, p. 162.) The weight of a detached part of a living body, like a leg or a hand, may be determined with considerable accuracy by displacement. A vessel is prepared, suitable in size and shape for the reception of the part to be weighed; it is filled with water, and the part in question thrust in. The volume of the water displaced, expressed in cubic centimeters, is multiplied by the average specific gravity of the part to be weighed, as learned from cadavers. The result is give in grams.

II. Instruments for Holding and Orienting Skulls and other Bones

A simple and perfectly satisfactory type of *osteophore,* especially suited to the long bones, has been already described in connection with the parallelograph above; namely, a retort stand, with an iron clamp. This would hardly be satisfactory for skulls, and here, owing in part to their peculiar shape, and more because of the need for an exact orientation, some special type is necessary for most purposes.

Craniophores.—Such a *craniophore* should have a pair of jaws, designed to be attached at the occipital foramen, the one outside and the other within; also a set of joints to allow the jaws, bearing the skull, to be moved in two directions at right angles with each other, for purposes of orientation. It is also convenient to be able to raise and lower the entire craniophore, or that part of it bearing the skull.

A simple form is shown in Fig. 10, in connection with the goniometer where the jaws are borne at the top of an upright piece, set into a heavy iron tripod, furnished with leveling screws. The jaws are provided with two joints, not well shown in the picture, which allow motion of the skull either forward and back or from side to side, and are borne, not upon the main upright, but upon an inner metallic tube, which slides in and out of the other, and allows the skull to be raised and lowered without altering its orientation.

Cubic Craniophore.—For certain work, especially for drawing with the diagraph, as described below, a great advantage comes from shutting the skull, properly orientated, and held in the jaws, within a skeleton cube, so that it presents the six normæ and thus may be drawn or photographed in any of them.

For this purpose the *cubic craniophore* has been devised (Fig. 12). It has been variously improved and varied for remedying certain defects, but in its main forms it appears as at *A*, where the jaws, with their orienting joints, have been taken bodily from the vertical form just described, and set into a socket in the middle of the floor (in the figure the entire apparatus has been reversed for use with the diagraph, which is also shown); or as at *B*, where the jaws and joints are held by a rigid arm, that comes out from one edge, and thus gets rid of the substructure which in the other form bears the socket.*

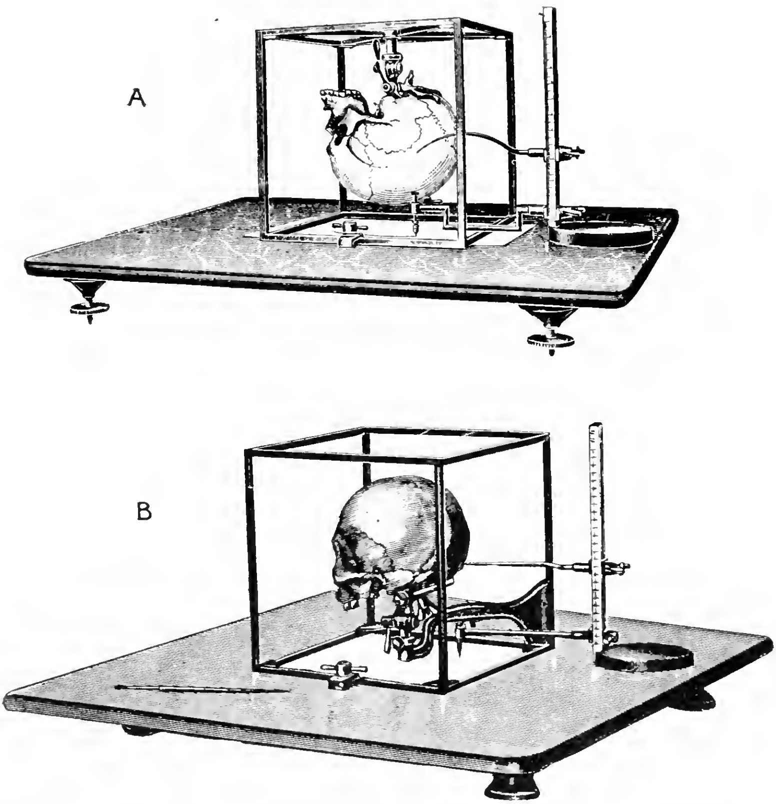

FIG. 12.—Cubic craniophore of Martin, used with his diagraph. The upper figure gives Martin's original model, in which to insure sufficient rigidity to the whole it is necessary to supply the bottom square (here the top) with a set of cross diagonals. In order to free the entire surface of drawing paper on which the craniophore stands, the whole apparatus is inverted, and the skull hangs from the middle of the upper plane. In the lower figure, equipped with the improvement of Schlaginhaufen, this inversion is not necessary, as the skull is borne upon a rigid steel arm which projects from one edge like an immovable bracket lamp, and quite frees the craniophore from all incumbrances like diagonals. The leveling platform used in connection with both craniophore and diagraph is a great convenience wherever a permanently level table top is not available. (*After Schlaginhaufen.*)

Horizontal Needle.—A convenient accessory instrument, the *horizontal needle,* consists of a small steel upright on a tripod, which bears, in a socket which may be raised and lowered, a cross needle which may be pushed in and out, precisely like the upper one of the two arms of the

* For the "Kubuskraniophor" here figured and described, cf. MARTIN, R.: Ueber einige neuere Instrumente und Hilfsmittel für den anthropologischen Unterricht, Correspondenzblatt der deutschen Gesellsch. für Anthropol. No. 11, 1903. (Versammlung in Worms.) SCHLAGINHAUFEN, O.: Beschreibung und Handhabung von Rudolf Martin's diagraphen-technischen Apparaten, ibid., No. 15, 1907.

parallelograph. When a skull is clamped into a craniophore, particularly one like that first described, and figured in Fig. 12, this needle may be used in placing the skull at the FH, the adjusting being continued until the needle, at a given level, by being pushed about the table on different sides, will successively point to the four essential points involved in this horizontal, the lowest point in the rim of each orbit, and the highest point in the rim of each auditory meatus. When a satisfactory orientation has been made in such a craniophore, the essential part, together with the skull, may be easily transferred to the cubic frame, without further adjustment. Except, however, for the upright parts of the cubic frame, the first orientation may be done just as well within the cubic craniophore, by the help of the horizontal needle.

Table.—It will be seen from this procedure, and still more from the description of the diagraph, to follow, that the *table*, although hardly an anthropometric instrument in itself, must be suited to the work. For these and other proceedings its top should be level and very smooth, and it would be as well to have it accurately leveled for such instruments as the stationary goniometer. Polished slate or plate glass is recommended for the surface, to which paper may be temporarily attached by means of wax or plastilina. For purposes where an instrument is required to be held stationary, as in the case of the cubic craniophore, during the drawing of diagraph curves, the same material may serve, placed along the base.

For purposes where a skull is simply to be held without orientation some very simple device is sufficient. For exhibition in a museum a standard with an upright bearing a spring or some arrangement of twisted wire is sufficient, and for many anthropometric purposes, such as drawing or photographing, a similar device is often satisfactory. A thin cloth cushion, nine inches square, partially filled with bran, serves a most useful purpose in all ordinary examinations of a skull, and in the measurements of arcs and linear distances. Upon such a cushion, if not very well filled, a skull may be placed in practically any desired position, leaving the two hands free for drawing; the cushion saves also the wear and tear to which a skull is subject, rolled about upon a table.

Universal Holder of Wetzel.—A device in which any sort of bone, in almost any degree of fragmentation, may be held with well-nigh mathematical exactness, convenient for the application of any form of drawing apparatus, is the *Universal holder* of Wetzel, Fig. 13. This apparatus, described in detail in Zeitschr. Morphol. und Anthropol., 1910–11, pp. 541–598, consists of a round stone table, upon which may be erected either one or two massive steel stands, which clamp firmly to the table edge. Various forms of clutch, fitted to various cases, are borne by the stand or stands, the firmest and best arrangement being one in which two stands are used, clamped at opposite sides of the table, and bear between them a horizontal steel bar. Whether supported by one or two stands this horizontal bar, suspended above the table, furnishes the attachment for the various clutch devices, which thus hold skull, skull-fragment or long bone, whatever its shape or size, directly above the table. In Fig. 13 the single stand is used, and the very irregular piece is held in the position desired.

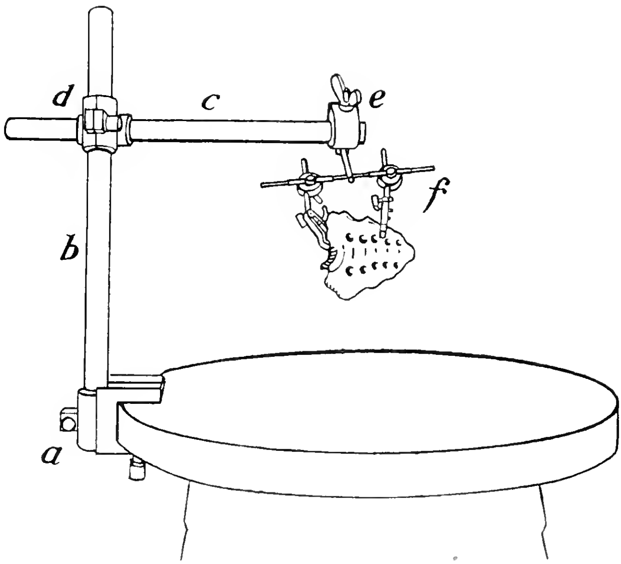

FIG. 13.—The osteophore of Wetzel. This is essentially a horizontal rod of heavy steel, upon which a variety of appliances may be attached to hold bones. This rod may be attached upon one side only, as in the figure, or upon both sides, as desired, or in accordance with the problem in hand. (*After Wetzel.*)

III. Instruments for Drawing and Delineating

Aside from the universally used photograph there are several forms of drawing instruments in common use for reproducting accurate lines of skulls and other bones.

Dioptograph of Lucae.—The *diaptograph* is essentially a pantograph, augmented by a telescope with a field crossed by spider lines which has for its purpose the selection of the exact lines to be drawn. The observer stands over the tube, and places the point of crossing of the lines in the tube over the lines he wishes to draw, sliding the tube gently with its felt-covered foot over a glass surface. Whatever lines are thus traced by the tube are reproduced by the pantograph at a distance, and by making use of the pantograph principle, and adjusting the frame, the reproduction may be made either larger, smaller, or of the same size as the object itself.

Perigraph of Lissauer.—In the Lissauer model, called by its deviser a *perigraph*, the stand consists of an upright upon a flat horizontal base.

to which it is attached exactly at right angles (Fig. 15). The upright bears a long, curved needle, which can be raised and lowered, and which is sufficiently curved to be out of the way of any projecting portion of the skull or bone which is being traced. The point of this needle (*d*), placed upon the desired level of a skull firmly held in a craniometer, traces around the perimeter, while a pencil (*g*) traces exactly the same

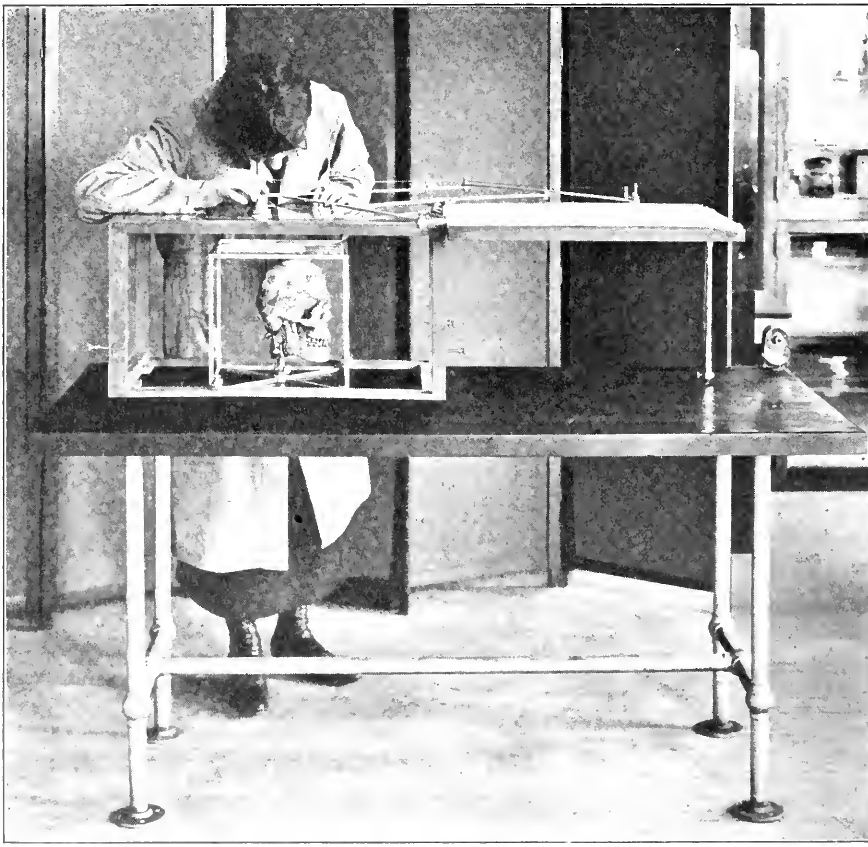

Fig. 14.—The dioptograph of Lucae in use. The operator is here following the contour lines of a skull as seen from the norma verticalis by means of the small telescope, and at the same time, by means of the attached pantograph, is sketching the same upon the sheet of drawing paper upon her left, mounted upon the drawing-board. As with other pantographs a skull may be thus drawn at a reduction or an enlargement, or can be drawn at exactly the natural size, as here.

curve upon a sheet of paper placed upon the table. In the figure, which is a little blind, the curved line proceeding from the pencil point is simply the curve which is being drawn, and not a second needle, as it seems.

Diagraph of Martin.—The form employed by Martin, called a *diagraph*, is figured in connection with his cubic craniophore in Fig. 12. The curved needle is similar to the one used in the previous instrument, but the frame is simpler, and consists of a felt-covered metallic foot, of oval form, which bears as the upright, a graduated steel rod. The curved

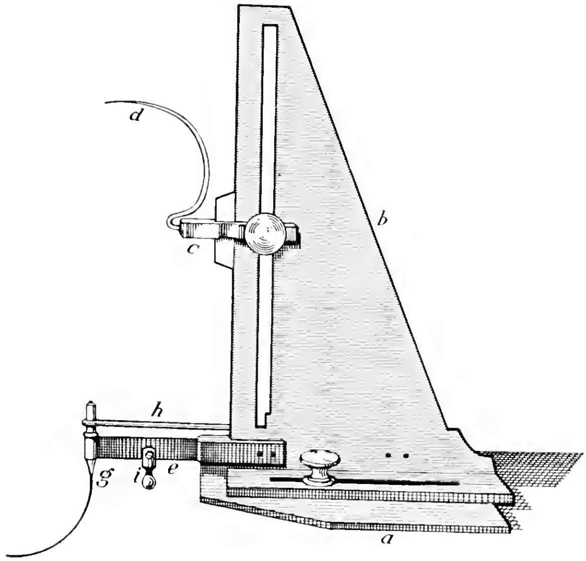

FIG. 15.—The perigraph of Lissauer, really a diagraph, differing but a little from that of Martin. (*After Wetzel.*)

needle may be rotated so that the curve lies at any plane without changing the exact position of the needle point above the pencil.

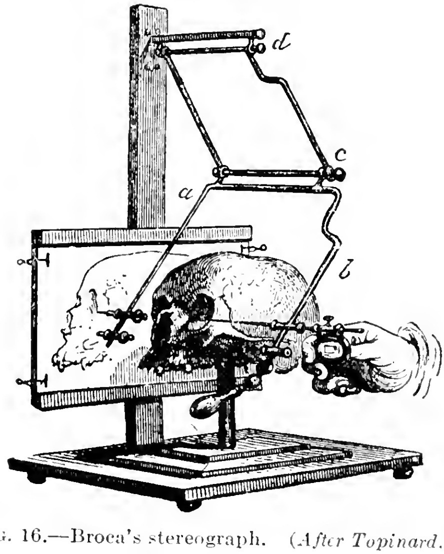

FIG. 16.—Broca's stereograph. (*After Topinard.*)

Stereograph of Broca.—In the *stereograph* of Broca (Fig. 16), we meet with another principle, that of a swinging stand that carries the needle and pencil as well, while the paper is held vertically, like an artist's canvas.

SIMPLE BIOMETRIC METHODS

I. Indices

The *Index* of a given measurement is its percentage when compared with some other measurement taken as a standard, or the equivalent of 100. It is thus a relative, and not an absolute, term, and may be compared directly with the corresponding index in another individual of different size.

For example, imagine three heads as seen from directly above; in one, which is long and narrow, the breadth is exactly one-half the length; in another the breadth is three-fourths the length; and in the third, which is absolutely circular in this outline the breadth and the length are equal. Now, if the *total length* were exactly the same in all, for instance, 160 mm., the three breadths would be respectively 80, 120, and 160, and they could be directly compared; if, however, they were not alike, we could say that in the first the breadth was 50% of the length; the second, 75%, and the third 100%, and these *proportions* could be compared directly, although the *actual measurements in millimeters* could not.

These are the indices, *i.e.*, the proportions of the breadths to the lengths. Whatever the actual lengths, they are considered to equal 100 in all cases, and the breadths are expressed as so many parts of that 100. The question is, if the length equals 100, what does the breadth equal?; or length : breadth :: 100 : x. This is solved by converting this expression into the following:

$$\frac{\text{breadth} \times 100}{\text{length}}$$

which will give the value of the breadth, in terms of the length, or, in other words, the *index*.

Illustration.—The total length of a given skull is 190 mm., and its breadth is 141 mm. We now divide the number, the percentage of which is to be found by the one which is to stand for 100, first adding two ciphers to the dividend, thus:

```
190)14100(74.21 index
     1330
      800
      760
       400
       380
        200
        190
```

The breadth, 141, is thus about 74% of the length, and this index is to be compared directly with the like index of any other skull, whatever its size.

Skulls of as large an index as 100 or as small a one as 50, mentioned in the explanation, do not exist normally, an index of 65 or one of 96 being extreme. Some 50% of all skulls have indices that fall between 75 and 80, and consequently these are called mesocranial ("mesocephalic"). Skulls below 75 are dolichocranial, and those above 80 are brachycranial. The one of this illustration is dolichocranial.

While it is usually more convenient, in using an index, to have the two distances taken at right angles to each other as here, it is by no means necessary, and an index may as well be used which takes two distances parallel to each other (as two across the face, $\frac{(\text{ft.} - \text{ft.}) \times 100}{\text{zy} - \text{zy}}$, No. 18 under Skull, below); or even one that uses the whole and a part of the same line; Ex. $\frac{\text{length of humerus} \times 100}{\text{total length of arm}}$. Although the distance to be reduced to a percentage is generally smaller than the one which represents the 100, this also is not necessary, and there are indices where the reverse is true, and where the value of the index is consequently more than 100.

II. Frequency Curves

When, after taking a large series of the same measurement in many individuals, we wish to compare its distribution, that is, the frequency of occurrence of each measurement, it is usual to construct a frequency curve, which will show the whole result at one stroke. This is done by the employment of paper with two sets of parallel rulings, at right angles to each other, the so-called "cross-section paper." Spaced horizontally from left to right along the bottom (or top) are placed the successive measurements, while along an upright on the left is placed a series of numbers, usually from 1 on, to indicate the number of individuals which are included under each measurement. The result of plotting the entire record out is a series of vertical columns of varying height, and the frequency curve is formed by connecting the tops of the columns.

Example: Suppose that, as the result of measuring 36 different objects, we find the result, giving each in millimeters, to be,

3, 5, 5, 5, 6, 4, 8, 4, 4, 6, 4, 6, 7, 3, 7, 6, 8, 10,
3, 4, 3, 5, 6, 5, 4, 4, 9, 5, 7, 9, 1, 6, 2, 5, 2, 5,

As they are found to vary from 1 to 10, we may then erect as many vertical columns, each of as many squares as there are instances of that particular figure, as follows:—

				5					
			4	5					
			4	5	6				
			4	5	6				
		3	4	5	6				
		3	4	5	6	7			
	2	3	4	5	6	7	8	9	
1	2	3	4	5	6	7	8	9	10

The top ends of the columns mark the position of the Frequency Curve which may be easily drawn.

As used in anthropometry frequency curves are most usually drawn upon a basis of groups of numbers, instead of using each consecutive one, 10 or 5 being convenient numbers to use in grouping. Thus the results of the measurement of the *length of the radius* in 100 students (females) were the following, grouped into groups each of five millimeters extent:

Extent in millimeters of each group	Frequency; *i.e.*, number of individuals within each group
210–215	1
215–220	1
220–225	5
225–230	11
230–235	12
235–240	12
240–245	16
245–250	8
250–255	9
255–260	7
260–265	5
265–270	4
270–275	1
275–280	2
280–285	4
285–290	2
	100

A frequency curve may be easily made from the above by erecting 16 columns, of which the first and second have a height of 1, the third one of 5, the fourth one of 11, and so on, the crest, which indicates in a general way the average of all, falling at the top of the seventh column, which is 16 units high. Where, as in this case, a short column intervenes between two taller ones, as at the thirteenth column, which is 1, followed by higher ones, it is an indication that the groups of units are too small, and tend to make a jagged frequency curve. In such a case the curve may be smoothed out by combining the groups into larger ones. If, for example, we combined these groups in pairs and had an interval of ten, instead of five, for each, we would avoid any such intermediate short columns, thus:

Groups, with 10-miliimeter intervals	Frequency (individuals in each group)
210–220	2
220–230	16
230–240	24
240–250	24
250–260	16
260–270	9
270–280	3
280–290	6

In this particular case the doubling of the intervals for the groups does not smooth out the drop near the right-hand end of the curve, but the entire curve becomes otherwise more symmetrical. The other way to smooth out an irregular curve is to increase the number of instances, measure another hundred, for instance, which would tend, by the doctrine of chances, to fill out the short columns.

One of the main uses of frequency curves is to show the general distribution of a certain set of measures or other statistics. The highest point in the curve marks the point of greatest frequency, the one that has the most votes, so to speak, and is called the *mode*. In the measurement of the same parts in two distinct human races, it may often happen that the modes of the two races differ from each other, which would be well brought out by superposing one curve upon the other. A bi-modal curve, or one with two crests, is sometimes found to be the result of the use of mixed material, that is, in anthropology, from the mixture of two differently proportioned races; and while this does not always prove to be the cause, such a curve always leads the anthropologist to suspect that such may be the case.

III. The Arithmetical Mean

This is what is usually referred to as the *average*, and is one of the first things to be ascertained from the usual results of the measurement of a certain length in a number of individuals. The most simple method of obtaining it is by actual summation, *i.e.*, adding the several results together, and dividing by the number of instances (individuals). Thus, in the following measurements of the *cristal breadth* (between the hips) of the same 100 students that furnished the radius length measurements, the arithmetical mean is calculated by actual summation:

Arithmetic Mean of the Cristal Breadth
(100 female students)

Items in groups	Frequency		Value of each		Total value
200–210	1	×	205	=	205
210–220	1	×	215	=	215
220–230	1	×	225	=	225
230–240	1	×	235	=	235
240–250	8	×	245	=	1,960
250–260	15	×	255	=	3,825
260–270	20	×	265	=	5,300
270–280	18	×	275	=	4,950
280–290	17	×	285	=	4,845
290–300	14	×	295	=	4,130
300–310	3	×	305	=	915
310–320	1	×	315	=	315
	100				27,120

27,120 ÷ 100 = 271.2, the arithmetic mean.

In this case it will be noticed that the value taken for each group is the *mid-value* between the two extremes of the group. There is still some little chance of error, since the separate individual measures may be anywhere between the limits of each group, yet the error is inconsiderable.

A second method of obtaining the arithmetic mean is by assuming a mean, which may be any mid-value in the list, and calculating the corrections. It is as follows:

Items in groups	f Frequency	d Deviation of the class	$f \cdot d$ Product	Σ Summation
200–210	1	−5	−5	
210–220	1	−4	−4	−22
220–230	1	−3	−3	
230–240	1	−2	−2	
240–250	8	−1	−8	
250–260	15 (assumed ave.)	0	0	
260–270	20	+1	+20	
270–280	18	+2	+36	
280–290	17	+3	+51	
290–300	14	+4	+56	+184
300–310	3	+5	+15	
310–320	1	+6	+6	

The first two columns are as before. An average is assumed, in this case we take the group with 15 instances, with the value of 255, the mid-value between 250 and 260, the two extremes of the group taken. We then prepare the third column, by marking the group taken as 0, and successively designating those that are lower as −1, −2, −3, and so on; while the larger groups are also successively, counting from the 0, +1, +2, +3, and so on. The fourth column is made up of the product of the items of the third and the second, the product of the number of instances into the class value of each group. These are summed up in two sums, the + and the −, the algebraic sum of the two is obtained, and algebraically added to the assumed average. This gives the actual average.

Here, assuming the average to fall at 255, we get, by multiplying column four by column three, the sum of −22 and the sum of +184. The algebraic sum of the two is +162, which should be multiplied by 10, the class interval, and then divided by 100, the total number of individuals used. This gives us, first, 1620, and then 16.20, which, having a + sign, must be added to the assumed average, 255, to get the true average, 271.2, the same as by the other method. If the reader should start with the same two first columns, and assume any other average, as, for example, 275 or 285, the final result would be the same.

This method is not any simpler to understand than the other, but has the distinct advantage of using lower numbers.

IV. Deviation

The arithmetical mean, or average, represents the value of each of the separate items if they were all evened up, with those which were more than the mean balanced up with those that were less to the same amount, yet it is probable that no single item of the entire list is the exact equivalent of the mean itself, but that each one *deviates* from this ideal, by so much more or by so much less. Now, it is important to know, in a given list, how much the items vary from the mean, in order to compare lists of different measurements, for the purpose of seeing how great the variation.

Now, the amount of variation, that is, whether all the items of a given list keep rather near the mean, or whether they swing away from it considerably, and thus show a large range of variation, is important to know. This cannot be done by selecting from the list the two extremes and comparing these, for this gives simply the *range* of variation, in which both extremes may be unusual while the rest vary but little from the mean. One must instead find the exact amount of deviation from the mean shown by each item on the list, add them all together, and divide by the number of items, which gives us an average or mean of the deviations, the *Average Deviation*, which takes into consideration, not simply two items but all of them.

This may, of course, be done by comparing each individual item with the mean, adding all together algebraically, and dividing this sum by the number of items, but, in a long series of items, such a method would be too laborious. This work may be materially shortened by using a method similar to that employed for getting the mean. As an illustration the average deviation of the preceding table of cristal breadths may be calculated as follows:

Items in groups	Frequency	Deviation from the mean	Summation	
210–215	2	12	24	
215–220	0	11	0	
220–225	0	10	0	
225–230	1	9	9	
230–235	0	8	0	
235–240	1	7	7	
240–245	2	6	12	
245–250	3	5	15	
250–255	5	4	20	
255–260	7	3	21	
260–265	7	2	14	
265–270	14	1	14	
270–275	12	0	0	271.20 mean
275–280	15	1	15	
280–285	8	2	16	
285–290	6	3	18	
290–295	7	4	28	
295–300	6	5	30	
300–305	2	6	12	
305–310	1	7	7	
310–315	1	8	8	

In the above list, which is grouped in fives instead of in tens, as in the table above, the group 270–275 is excepted, as containing the mean. The frequency is indicated in the next column, and in the next is indicated the rank of each group, above and below that containing the mean. In the fourth is placed the product of rank of each group with the frequency of each, and all, both plus and minus, are added together arithmetically, since the *amount* of the deviation, and not its direction, is sought in each case. This amount is found to be 126 minus, and 134 plus, or 260 in all. But as we have been considering groups of five units, the actual value of these deviations must be multiplied by 5, or 260 × 5 = 1300, and as the items included within the group which contains the mean do not count as deviating, this sum is divided by the total number of items, in this case 100, which gives the *Average Deviation*, if equally distributed to each item, as 13.00.

There are, however, several small errors not noted in the above, which may now be removed by a little calculation. If the mean were at exactly the mid-point of the group in which it lies, *i.e.*, 272.50, the calculation would be correct as it stands, but in this case it is a very little less than this, or 271.20, a discrepancy of 1.30, which should be subtracted from each item on the minus side of the line, and added to each on the plus side. The items represented on the two sides naturally balance in part, as may be found by subtracting the one group from the other, in this case 126 from 134, leaving 8 to account for; the sum of the deviation of these 8 items, each of which differs from the figure used by 1.30 ,or in all 10.40, must be added to the sum obtained before division; that is, 1300 + 10.40 = 1310.40. This corrects the items except those within the group 270 – 275, which may be supposed to differ from the mean by the same amount, 1.30. Hence the sum 1.30 × 12 (the number of items involved) or 15.60 must be also added, which will increase the total figure to 1326.00. When this amended sum is divided by the total number of items the corrected figure is 13.26, the correct *Average Deviation.*

For calculating the deviation of a series of numbers from a mean most statisticians recommend, instead of the above, the *Standard Deviation*, in which the calculations are based upon the squares of the successive deviations, rather than the simple numbers, and the final result is obtained by extracting the square root of the results thus obtained. This method yields more satisfactory results, but involves more that is purely mathematical.

IV—Coefficient of Variation

The calculation of deviation shows the actual amount by which the single items, on the average, deviate from the mean; in such studies as are discussed here, the actual number of millimeters. It is plain, however, that in a table which treats of short measures, involving, perhaps, 100 to 150 mm., an average deviation of 10 mm. shows a larger relative deviation than twice this amount would in a table such as the femur length, where the lengths involved run between four and five hundred millimeters. In order, then, to directly compare deviations from different tables, we need some sort of *index* which expresses the relation of the actual deviation to the actual mean. Such an index is the *Coefficient of Variation*, or "Coefficient of Dispersion," as it is also called, which uses the mean as the standard (=100), and compares with it the deviation, as follows:

$$\text{Coefficient of Variation} = \frac{\text{Deviation} \times 100}{\text{Mean}}.$$

In the example used here, where the average or Mean of the Cristal Breadths of 100 students is 271.20 mm., and the average deviation of the items is 13.26, the Coefficient of Variation is $\frac{13.26}{271.20}$ or 4.9 % of the mean. This figure gives thus the proportionate amount of variation exhibited by a certain measurement, as taken in a number of individuals, and may be compared directly with a similar figure taken from a different list, involving a totally different measurement. By such methods the amount of variation (proportionately) in the *radius length* could be compared with the amount of variation in the *femur length*, and the conclusion definitely taken as to which is relatively the more variable, in spite of he actual differences in the lengths of the two bones.

PART I

Osteometry; the Measurement of the Bones, Including the Skull*

I. THE SKULL

Orientation

Orientation of the Skull; Horizontals; Norms.—When a student takes a human skull into his hands in order to study, not its bones and other anatomical features, but its contours and proportions, and seeks to compare it in these particulars with a series of other skulls, he finds that the slightest change of position profoundly alters the contours to be examined and compared, and that it is consequently necessary to establish a fixed position for all, so that they may be properly compared. Furthermore, this fixed position must be universally used, as otherwise comparisons of the work of several investigators, especially in the use of photographs and contour curves, could not be made.

There is thus presented at the outset the question of *an exact, uniform position*, in which all skulls may be readily placed, and capable of application by all anthropologists everywhere.

Assuming, as we may, that skulls should be placed upright, with the median sagittal plane in a vertical position, the question resolves itself into determining the exact point at which the skull should be arrested in a rotation about a transverse axis, at right angles to this upright median plane; whether for example, it should be set as it naturally rests upon a level table, with the face canted back, or whether it should be raised to a position more in accord with that in which the head is habitually held in life. The first position suggested is certainly not advisable

* The author here and throughout this work use the term *Osteometry* in the larger sense of the measurement of the skeleton and its parts in distinction from that of the entire body when still clothed in flesh, or *Somatometry*. Historically the skeletal part first measured was the skull, to the study of which the term *Craniometry* was naturally applied, after which the word *Osteometry* was used for the remaining bones. Aside from the skull, in which a series of bones is immovably welded together to make a firm complex, thus forming a single subject for treatment, we have the pelvic bones, which have but little meaning when separated. For the measurement of this complex as a whole there has developed, as in the skull, a distinct term, the word *Pelvimetry*, and for other more or less closely associated series we may need eventually to coin such words as *Cheirometry*, *Podometry*, etc. There is no question, however, but that a word is necessary to signify the measurements of all the skeletal parts, and that that word is, *Osteometry*.

since a skull with the mandible attached rests at a very different angle from one without this part, and in the latter case it is impossible to make the proper substitution, or to know the height and other proportions of the missing part. Again, granting that a skull with mandible could be thus treated, the angular slant of the facial profile and of the forehead, characters essential to comparisons, would depend largely upon such points as the length of the chin, and the length or condition of the teeth, points which are of little anthropological importance, and have no reference to the more essential measurements of the skull.

The need was early felt, then, of the establishment of a *standard plane* defined in terms of topographical landmarks existing on the skull deprived of mandible, upon which a skull could always be placed preparatory to

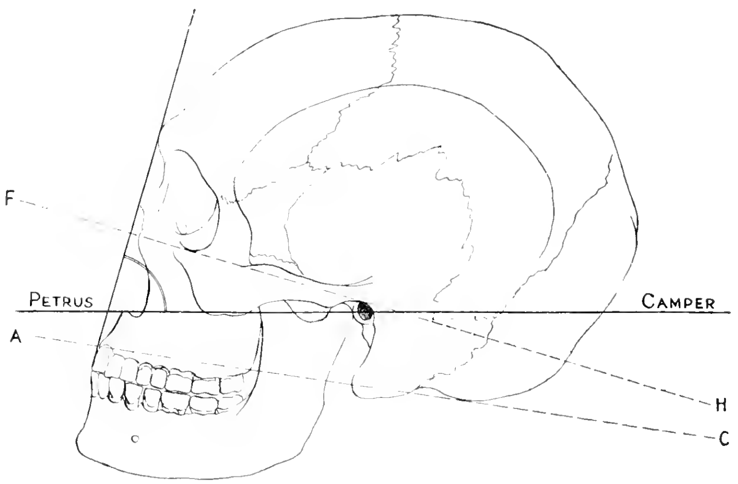

Fig. 17.—Skull placed on the horizontal used by Petrus Camper (1786).

examination, photography, tracing of contours, or any similar procedure, involving comparison. The early Dutch anthropologist, Petrus Camper, in his classical investigation of the *facial angle*, published posthumously in 1786, employed as the base a line drawn through the nasal spine and the center of the auditory meatus, and compared with this a line roughly tangent to the profile. The angle included between these two was the *facial angle*, while the lower line, which could be converted into a plane by including both meatuses, formed a horizontal plane upon which different skulls could be placed for comparison (Fig. 17). This plane, or "horizontal" was modified a few years later by Geoffroy de St. Hilaire (1795), who retained the auditory opening for the more posterior point, but changed the anterior one from the nasal spine to the free margin of the incisor teeth (Fig. 18). This was in two particulars a change for the worse, as it tilted the skull much too far back to be natural, and employed a point which necessitated the presence of teeth. Seeking to remedy these defects, Jules Cloquet (1821) proposed for the anterior point, not

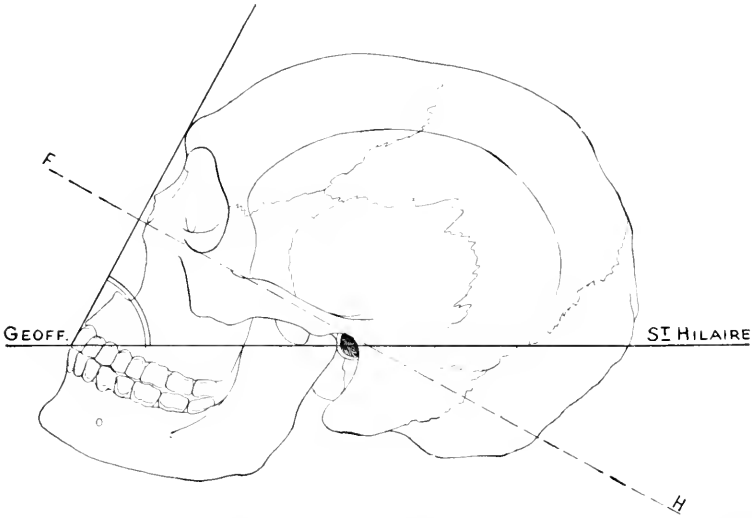

FIG. 18.—Skull placed on the horizontal used by Geoffroy de St. Hillaire (1795).

the free margin of the teeth, but that of the alveoli, while he still retained the center of the meatus posteriorly (Fig. 19).

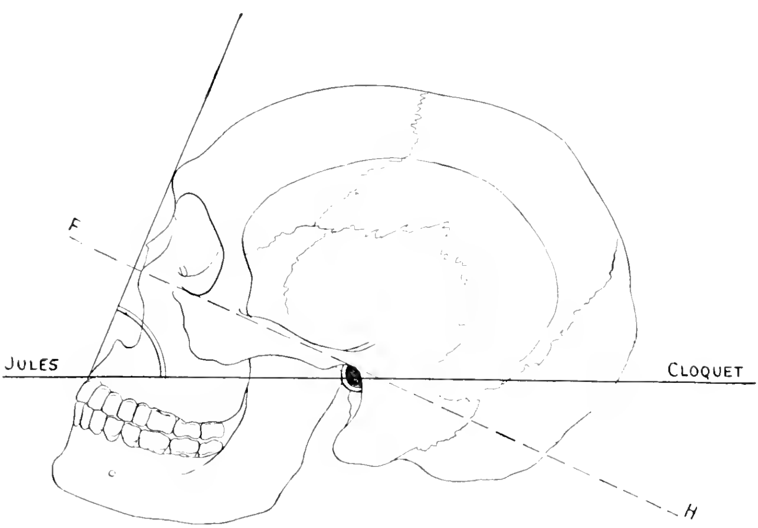

FIG. 19.—Skull placed upon the horizontal used by Jules Cloquet (1821).

Much later (1862) Broca established the famous *alveolo-condylar* plane, which, from its general use by French anthropologists, is often called the "French horizontal" (Fig. 20). This takes as the three points for the establishment of the plane the alveolar point of Cloquet, and, instead of the meatuses, the lower point of the occipital condyles, that is, the point upon which these parts would naturally rest. This is not far from the natural position of a skull deprived of mandible, when laid on the table, and is approximately parallel to the plane of the optical axes of the two eyes when looking straight forward.

Quite within the present generation another, and, we hope, final horizontal has been established, which has come into almost universal use, although there is still among the French a liking for the alveolo-

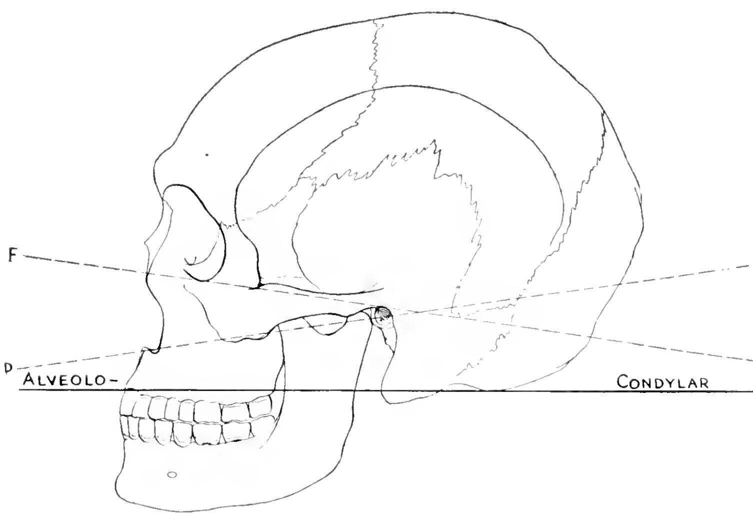

FIG. 20.—Skull placed upon the alveo-condylar plane of Broca (1862).

condylar plane of Broca. This is the plane established by the International Anthropological Association at a meeting at Frankfort-on-Main, and hence known as the "Frankfort Horizontal" (Fig. 21).* This, unlike the preceding, rests upon four points: the highest point in the margins of the two meatuses, and the lowest points in the margins of the two orbits. This has the one disadvantage of resting upon four points instead of three, so that, unless a skull is perfectly symmetrical, and few are, the plane has to be a sort of concession or approximation, but has

* The Frankfort Horizontal was first proposed at the meeting of the Craniometric Congress held at Munich in 1877; it was later ratified at the International Congress of Anthropologists at their meeting at Frankfort a/M, in 1884, hence the name.

Cf. ECKER u. HIS: Ueber die Horizontalebene des menschlichen Schädels. *Archiv. f. Anthropol.*, Bd. 9. 1877, pp. 271+.

GOLDSTEIN: Le plan horizontal du crâne. *Rev. anthropol.*, 1884. Series 2. T. 7. pp. 680 +.

GARSON, J. G.: The Frankfort Craniometric Agreement, with critical remarks thereon. *Journ. Anthropol. Inst.*, London. Vol. 14, pp. 64+.

the more than compensatory advantage of being almost equally determinable on the living; that is, the head of a living subject may be set up on the Frankfort horizontal as readily as a skull, and thus the two may be directly compared. It is also the claim of the originators, that this horizontal places a skull more nearly in the usual position during life than do any of the others.

In order to set a given skull upon one of these horizontals it is first put into a standard known as a *craniophore*, which consists essentially of two metal jaws controlled by a screw, the whole capable of turning in the three planes. The skull is clamped into this by using either the anterior or the posterior lip of the occipital foramen, and the skull

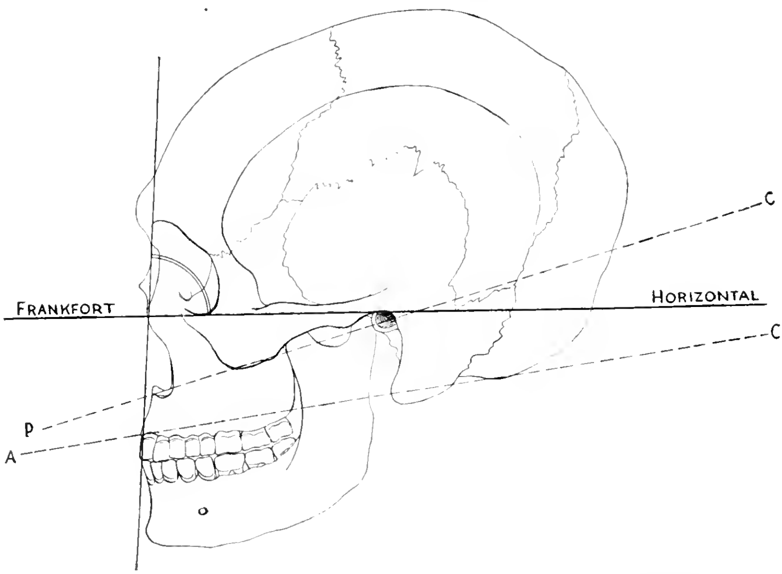

FIG. 21.—Skull placed upon the Frankfort horizontal (1884).

turned in the two vertical planes until the points in question are on the same horizontal plane, *i.e.*, at the same distance above the plane of the table upon which the craniophore rests. To determine this a vertical rod is used, set on a standard, and carrying an adjustible pointer. It is placed on the table with the craniophore, and placed in any position desired, while the skull is adjusted until the pointer, at the same level, points directly to each of the points used in determining the horizontal.

A skull, thus placed upon a horizontal, may be considered a cube with its six faces, although with irregular surfaces. The upper and lower faces are parallel to the given horizontal, or to the plane of the table, the two lateral faces are parallel to the median vertical plane, and the anterior and posterior faces are perpendicular to the four others. These four aspects, which are the ones used for comparison, and in the photography of skulls, are known as *normæ*, and are as follows:

norma frontalis........full front view.
norma occipitalis......back view, parallel to the foregoing.
norma verticalis........top view, from directly above.
norma basilaris........view of the base, parallel with the foregoing, but viewed from the opposite direction.
normæ laterales........There are naturally two of these, right and left. These (deztra et sinistra) are views taken directly from the side, and give their features in the reverse order. The full profile should be the same when traced from either side, but that seen from the right faces the right, and vice versa.

The Cubic Craniophore, described above (p. 20) is especially designed to define these six normæ by placing a skull in a cubic frame. When oriented according to the FH* the six faces of the craniophore coincide exactly to the normæ. The skull is thus exactly placed. For use with the diagraph, or for photography, and may be properly placed by resting the craniophore on the table upon any face, as desired.

Naturally a skull needs to be held in a craniophore and thus accurately oriented for certain purposes only, mainly for drawing, photographing, and tracing contours. For obtaining the ordinary measurements, and for examining the morphological peculiarities it is best placed on a table before the observer, and for the measurement of circumferences by means of the tape, it is most conveniently held in the lap. A simple and convenient device for much of the work consists of a *cloth cushion,* nine inches square and partly filled with bran. This is placed upon the table in front of the observer, and the skull put upon it. This not only saves much wear and tear of the skulls, which are likely to suffer from direct contact with the hard table top, but it will be found that the skull may be held by the bag in any position desired, thus releasing both hands for other work. Not only may many morphological features be thus conveniently drawn, as they do not depend upon orientation, but the majority of the measurements may be more easily made upon a skull thus firmly placed.

Landmarks

Landmarks Established on the Skull for Use in Craniometry. For use in the new science of *craniometry* Broca, an early French anthropologist, established a number of definite points on the skull surface, which were mostly without special anatomical significance and which were consequently without special anatomical names, but which became of importance to him as the termini of essential linear measurements. To many of these he gave distinctive names, such as *glabella, inion, bregma,* and so on, thus avoiding the inconvenience of using a long phrase

* The Frankfort Horizontal is commonly designated by its two initials, given in capitals, and will be so used throughout this book.

every time they were referred to. Other investigators have added to his original list until there are now nearly a hundred in general use, the most of which refer to precise points upon the skull surface, external or internal. A few, like the *euryon* and the *opisthocranion*, are located by geometrical relations, and not by exact topography, and are therefore variable in position. One, the *pteryon*, denotes a region, rather than a point.

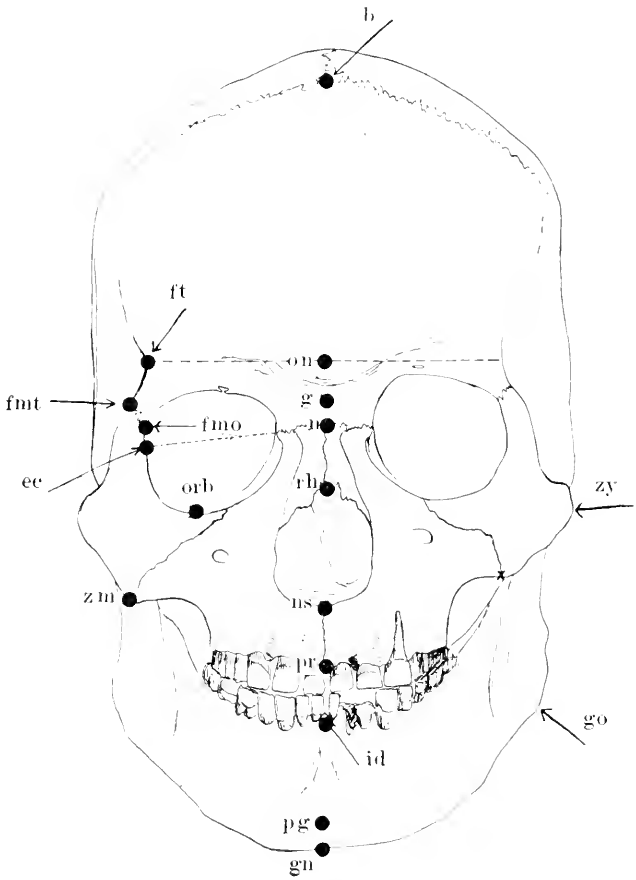

FIG. 22.—Anatomical landmarks on the skull, norma frontalis. For the meaning of the abbreviations, see the list on pp. 42–48..

The following list of such anthropological landmarks includes those in common use, with their customary abbreviations.* The arrangement is alphabetical. Points situated laterally, and therefore paired, are marked with a †; those not so marked are median.

* The abbreviations given here are those already in more or less general use, and should not be varied. When thoroughly learned they will be found convenient to use in notes and manuscript in place of the full names, and may serve as a convenient sort of shorthand which will save much time.

acanthion (acan) The point of the nasal spine, upon the lower border of the piriform aperture. This point, formerly much used, has now been mainly superseded by the *nasospinale*, q.v.

alveolon (alv) A point on the bony palate where a line drawn through the termini of the alveolar ridges crosses the median line. In practice this point is readily determined by placing a fine knitting needle across the palate, just back of the posterior ends of the alveolar ridge, and marking the point where this crosses the median suture of the palate bones.

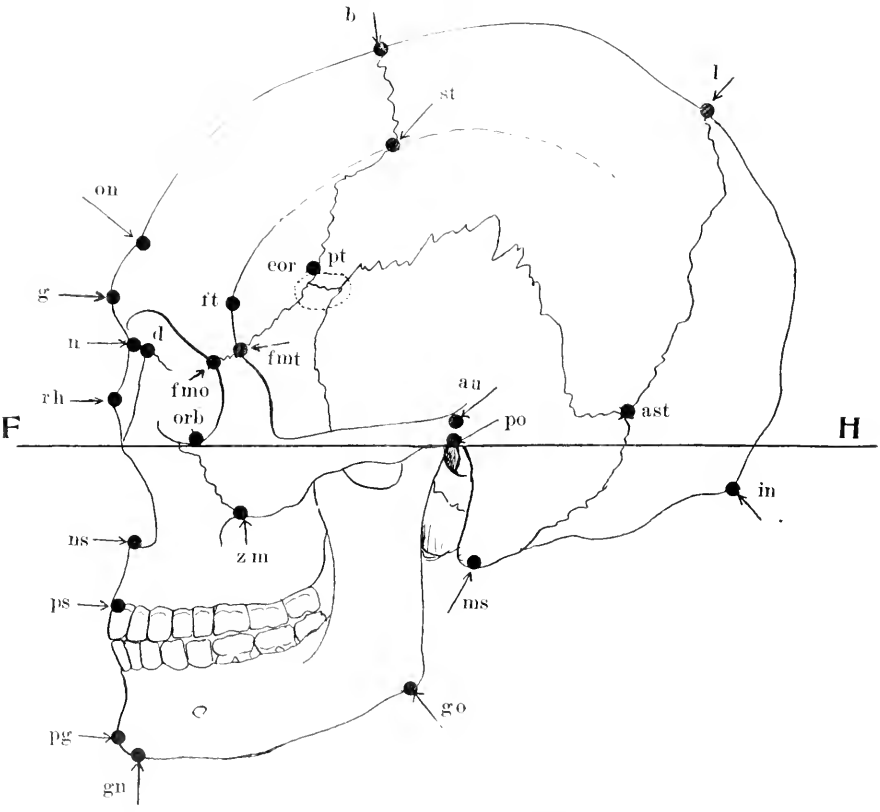

FIG. 23. Anatomical landmarks on the skull; norma lateralis. For the meaning of the abbreviations, see pp. 42–48.

asterion (ast) † A point behind the base of the mastoid process, where the lambdoidal, parieto-squamous, and occipito-squamous sutures come together, defining the boundaries of parietal, occipital, and temporal bones.

auriculare (au) † A point vertically above the center of the auditory meatus, and crossing the root or base of the zygoma. This point is but a few millimeters above the *porion*.

bregma (b)	The meeting place of the coronal and sagittal sutures; that is, the point of meeting of the two parietals with the frontal.
basion (ba)	The median point in the anterior margin of the occipital foramen.
condylion laterale (cdl) †	The most lateral point on the surface of the condyle of the mandible.
condylion mediale (cdm) †	The most medial point on the surface of the condyle of the mandible.
coronale (co) †	The two points in the lateral margins of the frontal which mark the termini of the maximum breadth of this bone. These points must be symmetrically placed with reference to the median line.

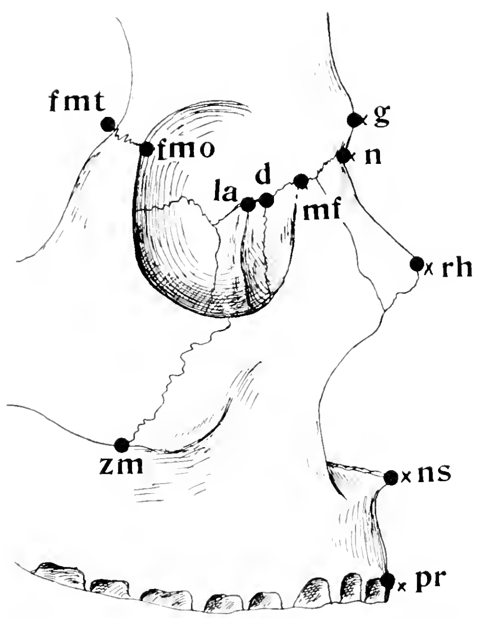

Fig. 24.—Anatomical landmarks on the skull; details about face and nose. For the meaning of the abbreviations see the list on pp. 42–48.

coronion (cr) †	The point of the coronoid process of the mandible.
dacryon (d) †	A point just within the inner margin of the orbit, where the lacrimo-maxillary suture meets frontal bone (Fig. 24).
ectoconchion (ec) †	The point where the orbital length line, parallel to the upper border, meets the outer rim. This line must be perpendicular to that measuring the orbital breadth.
ectomolare (ecm) †	The most lateral point on the outer surface of the alveolar ridge, opposite the middle of the second upper molar tooth; used in taking the maxillary breadth. (Fig. 25, x).

endomolare (enm) † — The most medial point on the inner surface of the alveolor ridge opposite the middle of the second upper molar tooth; used in taking the palatal breadth (Fig. 25, *y*).

euryon (eu) † — The two points opposite each other on the sides of the skull which form the termini of the line of greatest breadth.

frontomalare orbitale (fmo) † — The orbital end of the fronto-jugal (fronto-malar) suture, that is, its superficial part.

frontomalare temporale (fmt) † — The outer, or temporal, end of the foregoing.

frontotemporale (ft) † — The most medial point on the incurve of the temporal ridge, just above the fronto-jugal suture.

genion (gen) — The median point of the genial tubercles of the body of the mandible, lingual side.

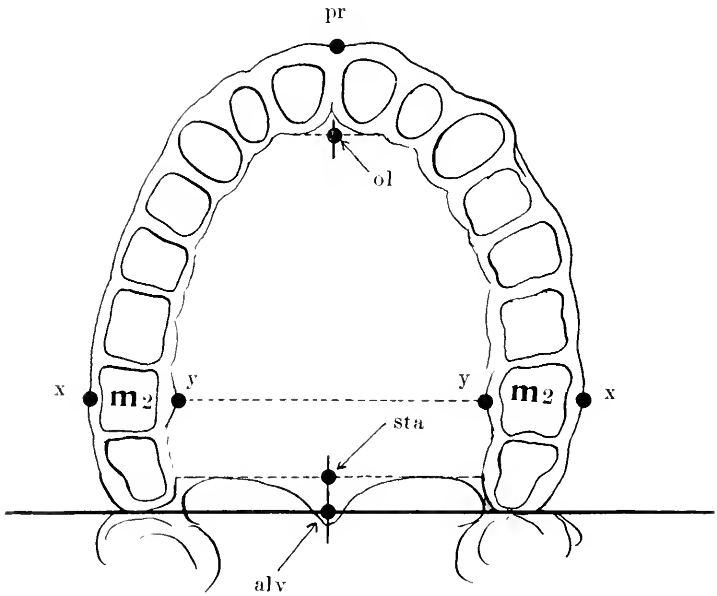

FIG. 25.—Anatomical landmarks concerned with maxillary and palatal measurements. For the meaning of the abbreviations see pp. 42–48.

glabella (g) — The most prominent point in the median line between the two eyebrow ridges, a little above the fronto-nasal suture.

gnathion (gn) — The lowest median point on the lower border of the mandible.

gonion (go) † — Literally, the angle of the mandible between body and ramus. In practice this is hard to determine in jaws with a rounded angle, but in cases where this is pronounced the point taken is the anterior lower corner of the square process forming the angle. Where the outline is softer and more rounded, by following the marginal contour backwards from the body, there is seen a slight curve upwards, immediately behind which there is at least the suggestion of a tubercle. This is the point taken as the gonion.

hormion (h) The median point in the suture between vomer and sphenoid; the median point where the former overlaps the latter. Seen in norma basilaris.

infradentale (id) The highest point in the anterior alveolar margin of the mandible in the median line, between the two medial lower incisors. It corresponds to the prosthion of the upper jaw.

inion (i) • This point, although one of the first employed and named, was rather loosely designated as the highest point in the occipital protuberance, or even as simply the occipital protuberance itself. It was furthermore considered to be the most posterior point in the outer surface of the skull, so that the "glabella-inion line," drawn between the two points named, was considered to measure the maximum length. In some skulls this may be the case, but more often such is not the case, hence the establishment of the *opisthocranion*, as the terminus of the maximum length line, which may or may not coincide with the inion. In the majority of skulls it may be defined in its original intention as the center of the occipital protuberance, although it should never be placed at or near the end of an elongated, downward-projecting process, which sometimes occurs. When the occipital protuberance is weak or ill-defined, the inion may be ascertained as the point where the superior curved (nuchal) lines cross the median plane.

An internal inion, the *endinion*, is located at the crossing of the crucial ridges which divide the cerebral and cerebellar fossæ. Its position may be determined by inserting the thumb into the occipital foramen, and when this is done the forefinger can readily determine the external point directly opposite it. Some observers use this external point, opposite the endinion, as the true inion, and determine it by this means, marking its position upon the outer surface with a pencil. In many cases these two inia will be found to coincide, but as this is not always the case, it is recommended for each investigator to state definitely which point he uses.

klition (k) A median internal point, best located in a median sagittal section, as in Fig. 26. It is the median point in the posterior margin of the sella turcica, which lodges the hypophysis in life, and is thus placed opposite the *tylion*.

lambda (l) The meeting place of the sagittal and lambdoidal sutures, of the two parietal bones with the occipital.

lacrimale (la) † The point of intersection of the posterior lacrimal crest with the fronto-lacrimal suture (Fig. 24).

linguale (li) — The upper terminus of the mandibular symphysis on the posterior, or lingual, aspect; the median point in the posterior alveolar margin of the mandible, on the other side of the bone from the *infradentale*.

lingulare (lg) † — The point of the *lingula*, or thin plate projecting over the inferior dental canal upon the inner surface of the mandibular ramus.

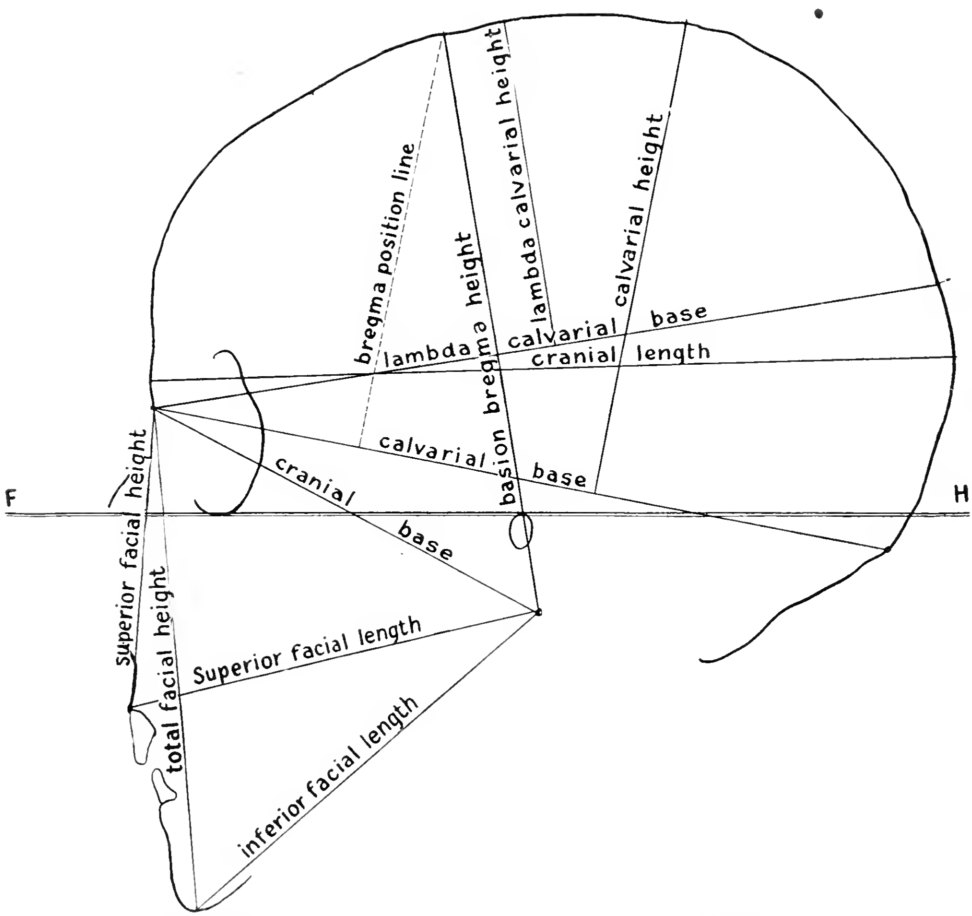

FIG. 26.—Certain important measures obtained from the median craniogram. This figure was taken from the skull of a female negro from the American Museum of Natural History, New York City, No. 997,745.

maxillofrontale (mf) † — The point of intersection of the anterior lacrimal crest, or the crest prolonged, with the fronto-maxillary suture (Fig. 21).

mastoidale (ms) † — The lowest point on the mastoid process; that is the point of contact with a table upon which the skull is placed, when resting upon its base.

mentale (ml) † — The lowest point in the margin of the mental foramen.

nasion (n)	The upper end of the internasal suture, where it meets the frontal bone; the point where the two nasal bones and the frontal come together.
nasospinale (ns)	This is practically the *acanthion*, the "nasal spine" of the older authors, but avoids the frequent errors caused by the varying degree of development found in this process. This point is defined as a point (usually within the bone substance), where a line tangent to the two lateral curves of the lower margin of the piriform aperture crosses the median line. In practice it is usual to take the lowest point of this margin upon one side of the median line.
obelion (ob)	The point in the sagittal, or interparietial, suture where it is intersected by a line drawn to connect the two small interparietal foramina. In the frequent cases in which there is but one of these, this point may be readily determined by it, and where both are absent, the point lies approximately at the place where the suturing is the simplest.
ophryon (on)	The point in the median line of the frontal bone where it is crossed by a line drawn to connect the two *frontotemporalia*.
opisthion (o)	The median point of the posterior margin of the occipital foramen.
opisthocranion (op)	This point is anatomically an indefinite one, and is simply the posterior end of the maximum length line of the skull, drawn from the *glabella;* the point where the posterior leg of the compass rests when spanning the greatest length. It may coincide with the inion, but is usually above this point. It is a synonym for *extremum occiput* and *occipitale*.
orale (ol)	A point in the bony palate where the line drawn tangent to the curves in the alveolar margin back of the two medial incisor teeth crosses the median line (Fig. 25).
orbitale (or) †	The lowest point in the margin of the orbit; one of the points used in defining the Frankfort Horizontal.
pogonion (pg)	The most projecting median point of the chin, on the anterior surface (mental process).
porion (po) †	The uppermost point in the margin of the auditory meatus; the points which, with the *orbitalia*, define the Frankfort Horizontal.
prosphenion (ps)	The median point in the spheno-ethmoidal suture upon the inner surface of the skull (Fig. 11).
prosthion (pr)	The lowest point of the intermaxillary suture, upon the alveolar margin, between the two medial incisors.
pteryon (pt) †	This is a region, rather than a point, and designates the upper end of the greater wing of the sphenoid, with the bordering bones, frontal, parietal, and temporal. Here the relation of these bones, and consequently of the sutures, is markedly variable, and is the subject of special anthropological interest.

rhinion (rhi)	The lower free end of the internasal suture.
sphenoidale (sphen)	A median internal point, best located in a median sagittal section as in Fig. 28. It is the median point of the anterior elinoid process, and thus marks the anterior margin of the sella turcica, opposite the *klition*. Called also *tylion*.
staphylion (sta)	The point in the median line of the back of the hard palate (interpalatal suture) where it is crossed by a line drawn tangent to the curves of the posterior margin of the palate (Fig. 25).
stephanion (st)	The point where the temporal ridge crosses the coronal suture.
subspinale (ss)	A median point where the base of the nasal spine passes into the alveolar portion of the upper jaw. This is best seen in a profile curve, where it lies at the deepest part of the inward curve. It is of use in the study of alveolar prognathism, as it marks the upper limit of the alveolar region of the maxillary. It lies about midway between *nasospinale* and *prosthion*.
supraglabellare (sg)	The deepest median point in the supraglabellar fossa. As this fossa is present only when there is some development of the superciliary ridges the point in question is frequently absent, or but slightly marked, especially in females, but when even a slight indication of it is present, its location can be made out in a profile median curve of the frontal bone. It serves to divide this curve into the two portions, *pars glabellaris* and *pars cerebralis*, the relative proportions of which aid in the determination of the relative size of the supraorbital crests. This point nearly coincides with the *ophryon*, a point now seldom used.
vertex (v)	The highest median point in a skull, when placed on the Frankfort Horizontal.
zygion (zy) †	The most lateral point of the zygomatic arch; a point determined by trial measurement and not by anatomical relations.
zygomaxillare (zm) †	The lowest point externally in the suture between the maxillary and jugal (malar) bones.

Measurements

Prescribed Measurements of the Skull; International Agreement of Monaco, 1906.—From the time of Broca individual anthropologists were in the habit of employing whatever measurements of the skull they found desirable, without regard to the work of others, and, in addition to this, did not correspond in the method of taking the same measurement. This had the advantage of gradually increasing the number of measurements employed, as new ones were being constantly devised by these independent investigators, but had the obvious disadvantage of rendering a direct comparison of the work of different craniometrists uncertain or impossible.

To improve this disadvantageous state of things the International Anthropological Congress of 1906, which met at Monaco in April of that year, appointed a committee to establish a definite list of the most commonly used and essential cranial measurements, to include also the precise method by which each should be taken.*
These measurements were presented under 32 numbers, although certain ones, like the "Cranial heights," and the "Measures of the bony palate," included several separate measures. A few were marked "facultative," to be further tried out before becoming canonical.

Since that time anthropometrists have endeavored to keep to these prescriptions, although they are considered purely as an expression of the general opinion, and not in any way binding upon the individual investigator. It is, however, to be expected that in case of departure from the prescription a good reason for such departure should be given, to avoid careless, or otherwise purposeless, variation from the generally accepted standard.

The measurements selected by the Agreement of 1906, are given here. In compiling them the original reports, as given in French, German, and English versions, were used, but the language used here is put into more recent form, and employs in the designations of termini many landmarks more recently determined, and precisely defined in the list above. They are the following:

A. The Skull Proper

1. *Maximum Cranial length;* the greatest diameter of the cranium in the median sagittal plane.

Anatomical points; in front, the glabella behind, the most salient point of the supra-occipital in the median line; the opisthocranium. Cr.

In taking this measure one point of the calipers is held upon the glabella, while the other is passed over the surface of the supra-occipital in the median line. The point which gives the maximum measurement is the opisthocranium, and this measurement is the one sought.

2. *Glabella-inion length;* this is similar to the preceding, except that a definite point, the inion, is used. This point is often difficult of exact location, however, and the value of this measurement may be considered somewhat doubtful (cf. above, under Landmarks *inion*). Cr.

3. *Maximum cranial breadth;* this is the greatest breadth that can be obtained while keeping the two points of the craniometer opposite each

* The members of this Committee were as follows: Waldeyer (*president*), G. Sergi (*vice-president*), Papillault (*secretary*), Hamy, Hervé, Lissauer, v. Luschan, Pittard, Pozzi, Verneau.

4

other; the maximum transverse diameter, perpendicular to the median plane. Cr.

4. *Cranial height*

(*a*) *basilo-bregmatic* (*basion-bregma*) *height;* from basion to bregma.

(*b*) *auriculo-bregmatic height;* the difference in level between porion and bregma. Several special forms of instrument have been devised for taking this measurement, but the simplest method, and fairly accurate after a little practice, is that of using the rod compass (the anthropometer put together in a special way (cf. above, under Instruments). The skull is held in the left hand, and the rod compass is held so far as possible in a plane parallel to the median sagittal plane of the skull. The upper leg should be drawn out longer than the lower one, the latter placed on the porion and the upper across the top of the cranium, directly upon the bregma.

5. *Least frontal breadth;* the distance between the two frontotemporalia. SC.

6. *Greatest frontal breadth;* the largest measure that can be obtained by the slide compass, both points of the instrument being placed on the lateral edges of the frontal bone; the distance between the two coronalia. SC.

7. *Bimastoid breadth;* the distance between the most lateral portions of the outer surfaces of the two mastoid processes, measured perpendicularly to the median plane (cf. modification of this below). Cr.

8. *Bizygomatic breadth;* the greatest breadth obtained by measuring across the zygomatic arches, perpendicularly to the median plane. The points where the two feet of the compass rest when this measurement is obtained are the zygia, movable points like the opisthocranium. Cr or RC.

9. *Nasion-basion line;* the distance between the two points named. Cr.

10. *Prosthion-basion line;* the distance between the two points named. Cr or SC.

11. *Nasion-gnathion line;* the distance between the two points named. The mandible must be put in place, the teeth in contact, and the condyles resting in the mandibular (glenoid) fossæ of the skull. SC or RC.

12. *Nasion-prosthion line;* the distance between the two points named. SC or RC.

13. *Nasal length;* the upper limit for this is the nasion; the lower is theoretically the nasospinale. Since this latter point is usually within the substance of the bony process forming the nasal spine, the lowest point of the lower margin of the nasal aperture, a little on one side of the median line, is used instead (cf. under Landmarks; *subspinale*, above). SC.

14. *Nasal breadth;* the greatest breadth found within the lateral margins of the nasal aperture, measured horizontally; *i.e.*, perpendicularly to the median plane. SC.

15. *Interorbital breadth;* the distance between the two lacrimalia (cf. under *Measurements slightly modified,* below). SC.

16. *Orbital breadth;* the inner terminus of this line is the dacryon, the outer that point in the outer rim of the orbit which gives the maximum distance from the dacryon. This latter is called the *ectoconchion,* a movable point. Let the line run as nearly as possible parallel with the upper and lower orbital rims, which are inclined to be fairly straight and parallel (cf. under *Measurements slightly modified,* below). SC.

17. *Orbital height;* the maximum distance between the upper and lower borders of the orbit at right angles to the previous measure (No. 16). In taking this avoid the supra-orbital notch. SC.

18. *Maxillo-alveolar breadth;* the distance between the two ectomalaria, *i.e.,* the most lateral points upon the outer surface of the alveolar ridge opposite the second molar teeth. This measure gives the maximum breadth of the alveolar ridge, and is to be taken at right angles to the median axis of the palate (the prosthion-alveolon line of the next measurement). Any exostoses or other projections, such as abnormal tooth roots, are to be avoided. SC or Cr.

18 (bis). *Maxillo-alveolar length;* the prosthion-alveolon line. The alveolon is determined by the use of a fine knitting needle laid across the posterior ends of the alveolar processes of the two sides. SC. The point where this crosses the median line is the alveolon (cf. above, u der *alveolon;* also Fig. 25).

19. *Measures of the bony palate* (tentative).*

(*a*) *Palatal length;* the orale-staphylion line. This is sufficiently described under the definitions of the two terms involved, under Landmarks; also shown in Fig. 25. SC.

(*b*) *Palatal breadth;* the greatest transverse breadth found within the inner limits of the alveolar arch. The termini are found along the inner (lingual) sides of the second molar teeth, at the point *v* in Fig. 25 (*entomalare*). The line is to be drawn at right angles to the prosthion-alveolon line. SC.

20. *Orbito-alveolar height;* the least distance between the lower border of the orbit and the alveolar border. This measure has been seldom used, and is now practically given up.

21. *Occipital foramen.*

(*a*) *Length;* taken in the median line, from basion to opisthion. SC.

(*b*) *Breadth;* taken at right angles to the former; the maximum breadth line. SC.

22. *Sagittal cranial arc;* the length of the curve of the cranium, measured along the median line with the tape measure, from nasion, over the vertex, to opisthion. For this measure the skull is most conveniently held in the lap, or upon the knee, and the tape applied along

* These two measurements, 19*a* and *b*, have now come into general use and are no longer to be considered tentative.

the external surface, being held down from point to point by the finger or thumb. The same technique is followed in the two following. TM.

23. *Transverse cranial arc;* taken from the projecting ridge at the base of the zygoma of one side, directly above the auditory opening, over the top of the skull to the corresponding point upon the opposite zygoma. The line must run in a single plane, and must include the bregma. TM.

23. (bis). *Horizontal circumference;* measured around the head, over the superciliary ridges in front, and the occipital protuberance behind, in such a manner as to get the maximum circumference, while keeping the line in practically a single plane. TM.

24. *Cranial capacity;* this is not a linear measurement, but the usual measurement of the cubic capacity of the interior cavity of the skull. The Committee made no decision concerning the exact method to employ relative to the material to be used, etc., but recommended the employment of several control skulls, that is, either actual crania or artifically constructed cavities of known capacity, which are to be used frequently (between each two or three measurements) to test the method; also, whenever possible, it recommends the use of water in a rubber container.

B. The Mandible

25. *Bicondylar breadth;* the greatest breadth between the lateral surfaces of the two condyles. SC or RC.

26. *Bigonial breadth;* the greatest breadth between the summits or apices of the two angles of the jaw, the gonia. SC or RC.

27. *Length (height) of ramus;* from the upper surface of the condyle to the apex of the angle (gonion). As this latter point is frequently difficult to determine with precision, take as this apex the point of intersection of the two lines drawn along the borders of the two parts involved, body and ramus. This measure may be made in a practical way by letting the mandible rest naturally upon a table, on its lower border, and measure from the surface of the table, along the posterior border of the ramus to the highest point of the condyle. SC.

28. *Breadth of ramus.*

   (*a*) *Minimum breadth;* the least distance between anterior and posterior borders.

   (*b*) *Maximum breadth* (tentative); the breadth across the upper end of the ramus, from coronoid process to the posterior border. The two legs of the slide compass (or rod compass) are placed so as to receive the ramus, one leg applied along the posterior border, the other tangent to the anterior border of the coronoid process. SC or RC.

29. *Symphyseal height;* the distance between the alveolar and the lower borders of the mandible, measured at the symphysis, in the median plane; the infra-dentale-gnathion line. SC.

30. *Height of the body of the mandible* (tentative); similar to the last, but taken in the vertical plane passing between the first and second molars SC.

31. *Maximum thickness of the body of the mandible* (tentative); taken in the plane used in the last measurement, between the first and second molars. SC.

32. *Mandibular angle;* this is the only angle included in the prescription of 1906, and records the inclination of the ramus to the plane of the body, *i.e.*, that of the table upon which the jaw rests when set upon its lower border. For this, a special instrument is required, which consists essentially of two boards, hinged together, and with a device for measuring the angle between them in all positions. The mandible is placed upon one of these, and the other shut down until it is tangent to the posterior border of the ramus.

Aside from the above measurement of the skull the committee also proposed some nineteen measurements of the head and face in the living subject. These will be found under their proper head (pp. 151–152).

LATER MODIFICATIONS AND ADDITIONS

This Agreement of 1906, with its prescribed measurements, has now been generally adopted, and forms the foundation of modern craniometry. A few of the original numbers have been discontinued; several have been modified; and a number of new ones added, the tabulation of which, added here, will bring the list of customary cranial measurements up to the present usage. There is, of course, no reason why an investigator should not make use of any selection or combination from this list which may suit his purpose, or why, if he has any special relation to show, he should not devise whatever new measurements he please, but in this latter case he must take care to define his new measurements with complete accuracy, so that others may follow him with precision.

I. *Measurements discontinued.*

No. 20. *Orbito-alveolar height* (on side of face).

No. 30. *Height of the body of the mandible* (on side of jaw).

No. 31. *Maximum thickness of the body of the mandible* (taken at the plane used in No. 30).

The last is still made use of occasionally. The two others were among those marked as *tentative* in the original prescription.

II. *Measurements slightly modified in later practice.*

No. 2. *Glabella-inion length.* This measure is now usually replaced by the nasion-inion, No. 33 below. This is also the case in the measurements based upon the diagraph tracing of the sagittal contour of the skull (cf. pp. 46, 58), where the perpendiculars used for the calvarial height, the bregma-position, etc., are erected upon the nasion-inion, and not the glabella-inion, as formerly.

No. 4*b*. *Auriculo-bregmatic height.* For this the general usage has become to employ for the upper limit, *not the bregma*, but either the *vertex*, or, more usually, to measure from the porion, *along a plane at right angles to the FH*, to the point in the upper contour where the line happens to fall. This measure is conveniently taken with the anthropometer, arranged as a rod compass, holding the instrument upon a plane judged by the eye to be at right angles to the FH. It will be seen that slight differences in position will make no appreciable difference in the result, and after a little practice a skull may be held in the left hand, and the rod compass in the right, and an accurate measurement made, which may be tested by comparing it with others made either by the same observer or by someone else.

No. 7. *Bimastoid breadth.* This measure is now taken between the two points of the two processes involved, instead of using their two outer surfaces.

No. 15. *Interorbital breadth.* For this the maxillofrontale is now preferred to the lacrimale. When both are used they are distinguished as anterior and posterior respectively.

No. 16. *Orbital breadth.* With the definite establishment of the three closely adjacent landmarks, maxillofrontale, dacryon, and lacrimale, it is clear that any one of them could be used in obtaining this measurement. The Monaco Agreement calls for the dacryon. The other two are also frequently used, and some craniometrists employ all three, the better to compare with all previous work.

No. 23. (bis) *Horizontal circumference.* The Monaco Agreement specifies that the tape should pass over the superciliary ridges. Some now employ, usually as a second horizontal circumference, one that passes over the ophryon.

III. *Added measurements, not included in the Monaco Agreement, but which have now come into general use.**

33. *Nasion-inion* length; a variation of the glabella-inion, as explained above, under II, No. 2. Cr.

34. *Gnathion-basion;* measurement taken with the mandible in place. between the two points named. Cr or SC.

35. *Biauricular breadth;* from one auriculare through to the other. Cr.

36. (*a*) *Outer biorbital breadth;* between the two frontomalaria temporalia (fmt-fmt). SC.

(*b*) *Inner biorbital breadth;* between the two frontomalaria orbitalia (fmo-fmo).

* These added measurements are compiled from the measurements on the forms used for the craniometric data of a skull at three different institutions in the year 1913, one German, one Swiss, and one American; viz., Freiburg, Prof. EUGEN FISCHER; Zürich, Prof. OTTO SCHLAGINHAUFEN; and the Peabody Museum at Harvard.

37. *Maxillary breadth;* between the two zygomaxillary sutures, at their lowest external point (zm-zm).

38. *Greatest occipital breadth;* the distance between the two asteria (ast-ast). This measures the greatest breadth of the occipital bone along its lateral sutures, and corresponds to the measurement of the *greatest frontal breadth* (No. 6). SC.

39. *Frontal arc;* the distance nasion-bregma, over the surface. TM.

40. *Parietal arc;* the distance bregma-lambda, over the surface. TM.

41. *Occipital arc;* the distance lambda-opisthion, over the surface. TM.

These three last, 39, 40, and 41, added together, should equal the measure of the *total cranial arc*, No. 22. The exact points used for bregma and lambda may be marked by a pencil line, to insure the use of the same point for two consecutive arcs, or the judgment may be put to a severer test by measuring each arc by itself, without reference to the rest. In a well-marked skull it will be found that these measures, however taken, will correspond within a millimeter or two.

42. *Frontal chord;* the distance nasion-bregma, in a straight line, as measured by the slide compass. SC.

43. *Parietal chord;* the distance bregma-lambda, in a straight line, as measured by the slide compass. SC.

44. *Occipital chord;* the distance lambda-opisthion, in a straight line, as measured by the slide compass. SC.

These last three measures, 42, 43, and 44, may be also measured upon the diagraph tracing of the median sagittal curve, and if the two methods are correctly used, the two should correspond. Certain other distances, as *basion-bregma, nasion-basion,* etc., may be also measured upon the diagraph curve, and a comparison of the two methods will prove each other. Aside from a number of important angles, the craniogram furnishes much the best, or sometimes the only method of obtaining certain other important linear measurements, such as the calvarial height, the lambda calvarial height, and the bregma perpendicular. These will be considered below, under the subject of the median sagittal craniogram.

45. *Mandibular length;* the distance between the anterior point of the mandible and the median point of a line drawn across the posterior surface of the two gonia. Place a knitting needle across the back of the gonia, and measure from the middle point of this to the anterior limit of the jaw, anterior surface, both in the median sagittal plane.

Measurements to be Obtained from the Median Sagittal Craniogram

Many of the above measurements of cranium and face may be taken upon the median profile curve of a skull, when drawn accurately by means of the diagraph. Of all craniograms, or tracings thus made, this one, the median sagittal, is by far the most important, and is so emphatically *the* craniogram *par excellence*, that it is the one always referred to when the word is used without modification. (cf. Fig. 26, p. 46).

Quite aside from its use in furnishing another method of presenting the more usual lines, and thus corroborating the results of direct measurement, there are certain important internal lines, such as the *calvarial height line*, or the *bregma position line*, that are obtainable in no other way than by means of this craniogram. Especially, however, in the presentation of various angles, mainly internal ones, lies the chief usefulness of this figure, where they need merely to be constructed by means of lines drawn between the proper points, and then read off with a transparent protractor.

The most important data obtainable from such a craniogram may be presented here in three groups; *corroborative measurements*, *linear measurements*, and *angles*.

1. *Corroborative Measurements*

Any linear measurements that may also be taken directly on the skull will serve to test the accuracy of a craniogram, but the longer the line employed, so much greater is the visible error, and the severer the test. Thus the two best measurements for this purpose are the two greatest dimensions of the profile view, the maximum length and the basion-bragma height. In making this test a discrepancy of 1 mm. or so is not a serious one, as it may be accounted for in large part by the varying width of the pencil point, or a slightly oblique position of the median axis of the pencil. Such slight discrepancies should be corrected in the craniogram by erasing and redrawing portions of the curve, yet such corrections should not be attempted if they involve much more than the breadth of the pencil mark.

In this enumeration, as everywhere throughout this book, measurements *bear the same numbers as when first mentioned;* all measurements taken from the foregoing list, therefore, will here have the former numbers, (between 1–45) while those first introduced here are furnished with numbers from that point on. This will make it easy to precisely designate a given measurement anywhere in the text, and to readily look up its precise specifications in the list in which it is described in full.

1. *Total cranial length;* the ruler is to be applied to the craniogram, holding the zero point on the most bulging point of the glabella. The point of maximum length can be readily found by slightly rotating the ruler about this anterior end, until the furthest distance is secured. This should naturally correspond to the same, obtained by the craniometer from the skull, allowance being made for the width of the pencil mark at either end, 1 mm. or so for each.

4*a*. *Basion-bregma height;* this should correspond within about the same limits as the previous one.

[The correspondence of these two lines, placed nearly at right angles to each other, in both craniogram and in the skull by direct measurement, will usually establish the practical correctness of the former. Where, however, the special accuracy of a particular region is desired, use may be made of other lines, such as the nasion-basion, or the basion-prosthion, if the discussion especially concerns the facial region; or in the chords and arcs involved, while investigating a profile contour.]

2. *Important Lines*

The most of these may be taken also direct, and hence have already found a place upon the previous list. Many, however, serve here in the construction of some important angle; as a base for some special perpendicular; or otherwise in some special relation, which makes it convenient to designate them by other names. These new names are given here, but the lines themselves may be recognized by their numbers, which are the same as in the previous list. The old names also are added in parenthesis. (cf. Figs. 26, 27, 28).

33. *The calvarial base* (nasion-inion line). This line serves as the base upon which the calvarial height line [48] is erected.

9. *Cranio-basal length* (nasion-basion line). This line serves as the entire length of the basis cranii, from the anterior edge of the occipital foramen, forward to the anterior limits of the skull. Few people, even anatomists, realize to how great an extent the axis of the human skull has become shortened and bent together; bringing the occipital foramen almost in contact with the posterior nares, and placing it about in the center so that the heavy head, in the erect position of the body, is almost balanced upon the top of the vertebral column.

10. *Facial depth* (prosthion basion line).

34. *Inferior facial depth* (gnathion-basion line). As the gnathion properly lies *underneath* the jaw, where it serves as the limit for lines of measurement coming from the direction of the nasion, it is more natural to draw this line, from the basion, not to the gnathion, but to the most anterior point of the jaw, which is about at the pogonion. It may be possible ultimately to remedy this inconvenience, even to the establishment of a new landmark, between pogonion and gnathion, but at present the gnathion is the point specified, and one should be careful to use it, bringing the termination of the Inferior facial depth line, and that measuring the total facial length [11] to the same point.

12. *Superior facial length* (nasion-prosthion line). [This line, taken with that of the superior facial length and the cranio-basal length, forms an important triangle, which is practically coincident with the nasal cavity. This may be found of importance in the future study of the

proportions of this part; the most important angle will probably be found to be the one with apex at the basion (n-ba-pr), as it subtends the superior facial length.]

11. *Total facial length* (nasion-gnathion line).

46. *Nasion-lambda line.* This, although capable of direct measurement, is not used otherwise than in the craniogram, where is serves as the base for the lambda calvarial height [49], as the nasion-inion line serves for the calvarial height [48]. Of itself, this line and its measurement, has not been found of value.

47. *Basion-lambda line;* the main importance of this line is its participation in forming the great cranial quadrilateral, nasion-bregma-lambda-basion, described below.

42. *Frontal chord* (nasion-bregma).

43. *Parietal chord* (bregma-lambda).

44. *Occipital chord* (lambda-opisthion).

48. *Calvarial height;* the longest perpendicular that can be erected upon the nasion-inion line [33] within the medial contour curve of the cranium.*

49. *Lambda calvarial height;* the length of the perpendicular erected upon the nasion-lambda line [46], precisely as in the case of the calvarial height [48].

50. *Bregma position line;* this is a perpendicular, dropped from the bregma upon the nasion-inion line, the point where it touches the latter designating the *bregma position.* This line differs from most in that it has little value in itself, but is used to determine an important point. This point may be made available for comparison by forming an index the numerator of which is the distance along the nasion-inion line from nasion to the bregma position point, and the denominator the entire nasion-inion line [index 36, below].

51. *Frontal perpendicular;* the longest perpendicular that can be erected upon the frontal chord, within the limits of the frontal arc. This line is important in itself, and also in its definition of the point where it touches the arc, and marks the apex of the *frontal curvature angle.*

52. *Parietal perpendicular;* specifications and uses like that of the previous one, save that it concerns the parietal bone.

53. *Occipital perpendicular;* specifications and uses like that of the two previous ones, save that it concerns the occipital bone.

3. *Other Possibilities of a Craniogram*

A craniogram, as a contour tracing, does not contemplate the locating of any point not included within this outer contour, like bregma, lambda,

* The first calvarial height proposed used the glabella-inion, instead of the nasion-inion, for the base. This was by G. SCHWALBE, in his study of *Pithecanthus erectus*. cf. Zeitschr. Morphol. u. Anthropol. Bd. I. 1899, pp. 38+.

etc. It is quite possible, however, to find with the needle of the diagraph certain essential points upon the lateral surface, and thus to indicate them also upon the craniogram. By thus locating porion and orbitale, for instance, the FH may be drawn in upon a craniogram, often a great advantage in getting relationships; while by drawing lines from these points to those upon the outer contour, certain unexpected new lines and angles may be formed, some of which may be found to be of much service. When a craniogram is made from a skull properly oriented within a cubic craniophore, a tracing of the frame of the craniophore, drawn about the craniogram, will serve to orient it, and, if either one of the points that are used in the determination of the FH be present, this important horizontal may be added.

Measurement of the Cranial Capacity.—This procedure, No. 24 of the prescriptions of 1906, is a very old one, and developed early in cranial investigation. It consists essentially in first filling the entire cranial cavity with some material consisting of small, dry, granules, and then measuring it accurately by pouring it out into a graduated glass cylinder. There are, however, many chances of error in this procedure, which have been so far as possible eliminated by various devices.

In the first place the larger orifices of the skull, except the occipital foramen, which is left for filling and emptying, are plugged with cotton, taking care not to allow the cotton plugs to project into the interior. The material to be used in measuring is then poured in by means of a tin funnel, the skull being held with the occipital foramen uppermost. For filling material different investigators have employed sand, mustard seed, canary seed, peas, small shot (No. 8), glass beads and other things. Recently attempts have been made to use a liquid, water or mercury, in conjunction with a thin rubber bag, which expands as filled, and assumes the shape of the cranial cavity, and in the prescription of 1906 water is to be used "whenever possible." A liquid has the decided advantage of being non-compressible, and thus of occupying the same space in the measuring cylinder as in the skull, insuring an exactness of result not possible with the dry media, which can be compressed to a considerable extent.

Naturally a dry medium has in practical application a decided advantage over a liquid, and the chance of error through a different amouut of compression in skull and cylinder has been reduced to its lowest terms through an improved technique. Perhaps for general purposes some small seed is the best, and of the various possibilities millet-seed, as recommended by Martin, is the best of all. This seed, not always easy to obtain in the United States, is lenticular, not spherical, and has a very smooth coat, and thus packs closely together, the individual seed slipping into place very easily. Mustard seed is also good, but the spherical seeds do not pack so completely, and the coat is not as smooth as millet.

In filling, either the skull or the cylinder, the main point is, *not to pack*. There is a great temptation to do so, and the beginner will almost invariably press on the seed, through the occipital foramen, with his finger, with the intention of completely filling the space. In all cases, however, the rule must be invariable, to let the medium fall naturally, the separate granules arranging themselves as they will, without forcing them to fit together more tightly than they do under the influence of gravitation. In the same way neither skull nor cylinder is to be shaken or thumped down upon the table, for such procedures tend to pack the medium more tightly together, and cannot well be administered in both skull and cylinder to the same degree. To insure a uniform fall of the medium into the cylinder a simple apparatus has been devised in the form of a large tin cup of about 2000 cm. capacity, and with a funnel-shaped bottom having a round hole, 2 cm. in diameter, precisely in the center. This hole may be opened or shut from the outside by means of a simple rod apparatus, which slides a flat cover to and from the hole. The cup receives the seed, or other medium, directly from the skull, poured from the occipital foramen, and is then placed upon the 2000 cm. glass cylinder, exactly centered with it and the whole apparatus placed upon a perfectly level table. The hole is then opened, and the seed pours down in a uniform column through the center of the cylinder, falling at the bottom in the center and distributing itself evenly upon all sides. When properly done the surface of the seed should present a slightly convex surface, which can be readily made level by the use of a flat disc of wood on the end of a rod, the disc being a little smaller in diameter than the inner dimensions of the cylinder itself. Even here care should be taken not to compress the seed, but to simply level the surface so that it can be more accurately read, which is done by a gentle patting, accompanied by a slight twisting of the rod.

Unfortunately the same precision cannot be obtained in filling the skull, but a result similar to that obtained by the tin cup may be produced by dropping the medium through the occipital foramen through a tin funnel which is kept supplied with seed, and held up so that the stream of seed falls from a like distance. Towards the end, a slight use of either the finger, or a small wooden cylinder, is required, to fill the lateral spaces at the top, but no especial pressure is to be exerted, and the action is to be limited to about the same amount that is used in the cylinder in leveling the top. By thus employing merely the natural amount of packing incident to the material used when falling naturally, and taking care not to exert pressure, the result should be uniform in skull and cylinder, and the latter should register the actual cranial capacity of the skull thus measured.

As a check on the method, and a test as to whether the results are accurate or not, the method of using a "control skull" is advocated. This is either a real human skull of known capacity, or one made of bronze, glass, or some other hard material, the exact cubic contents of which is known. The control skull is measured every little while during the work, perhaps between every two or three skulls, and the result compared with the known capacity. A marked discrepancy shows that the work is not being done right, and will indicate whether the medium is too much or too little compressed.

A natural skull is made into such a control by sawing off the skull-cap in the usual manner, and then treating the entire inner surface with some waterproofing mixture, plugging all the foramina, and finally cementing on the skull cap by the same material. This is then waterproof, and may be accurately measured by this medium, the result of which is definite and invariable. Then when thoroughly dried out it is ready for use. The exact capacity should be clearly marked upon the skull itself. It is to be marked that this result is not necessarily the original capacity of the skull, but that it is probably modified by the waterproofing cement. It is now simply a receptacle of known capacity and with the exact shape of the receptacles with which the anthropometrist is dealing, thus reproducing the exact conditions presented with the normal skulls.

Finally, as mainly a convenience, in laboratories where there is much of this work going on, a special table should be provided, with a concave top, sloping downward towards the center, where there should be a small hole, communicating with a receptacle placed underneath, through which the extra grains of the medium, the constant spilling of which is inevitable could be collected and returned to the proper place. As a matter of convenience the top of the table should be large enough to hold the utensils employed, and should be in close connection with a level portion, where the filling of the cylinder and similar work could take place. Each laboratory will easily work out the details of such a piece of furniture for itself.

While the cranial capacity is an indication of the weight of the brain, the two are by no means the same. Even were the specific gravity of brain substance the same as that of water, there would be a discrepancy, for the cranial cavity contains, not only the brain, but the wrappings, and blood vessels which including the venous sinuses, present together a considerable volume, which if there were nothing else, would make the weight of the brain in grams considerably less than the cranial capacity in cubic centimeters. But, aside from this the specific gravity of brain substance is a little lighter than water, a circumstance which would still further decrease the number in the reduction of cubic centimeters to grams.

Taking all things into consideration, including the fact that in heads of different size the proportions of brain weight to cranial capacity vary also, Welcker, in 1886, prepared the following table, which is perhaps, the best we have at present (Martin, p. 640).

Where the cranial capacity is between 1200–1300, take for each

With a cranial capacity of	Take for each 100 cc. a brain weight of
1200–1300	91 grams
1300–1400	92 grams
1400–1500	93 grams
1500–1600	94 grams
1600–1700	95 grams

Bolk (1904) gave the following table of the percentage of brain weight to cranial capacity at the different ages of life. It will be noticed that this is the greatest at 50, after which, through senile changes, the weight of the brain decreases, while the cranial capacity naturally remains the same.

Age, years	Percentage of brain weight to cranial capacity
30	73.7–94.0
40	90.0–96.5
50	90.0–95.2
60	89.2–93.4
70	88.1–93.8
80	85.2–90.1
90	84.1–88.4
over 90	81.5

Earlier Manouvrier, without considering the matter as to the age of life, gave, as a general average of the percentage of brain weight to cranial capacity, 87 %. No author has found any notable sexual difference.

Indices

Indices of Cranium and Face, with Classification of Values.—The following list of Indices includes the most of those which have been found of value in craniological comparisons thus far. As they are merely a simple numerical method of expressing the relationship of definite parts and have been devised to express more precisely certain differences to which the attention of the observer has been called, it is to be expected that, with the inauguration of new comparisons, there will appear from time to time new indices to express them. Indices of the skull involving direct measurements, may be conveniently grouped as those of the *Cranium*, those of the *Face*, and those which express *Comparisons* between the two. These are followed by those derived from the *craniogram*.

I. INDICES OF THE CRANIUM

1. *Length-breadth index* $\dfrac{\text{maximum cranial breadth [2]} \times 100}{\text{maximum cranial length [1]}}$

Classification of Values

ultradolichocranial*	below 65
hyperdolichocranial	65–70**
dolichocranial	70–75
mesocranial	75–80
brachycranial	80–85
hyperbrachycranial	85–90
ultrabrachycranial	90+

[This index is available for the living, but the values of the separate classes are to be advanced one point. Thus, a brachycephalic head (living) runs, not from 80 to 85, but from 81 to 86, and so on].

2. *Length-height index* $\frac{\text{basion-bregma height [4}a\text{]} \times 100}{\text{maximum cranial length [1]}}$

chamaecranial	below 70
orthocranial	70–75
hypsicranial	75+

This index is obviously not applicable to the living.

3. *Length-auricular height index* $\frac{\text{auricular height [4}c\text{]} \times 100}{\text{maximum cranial length [1]}}$

chamaecranial	below 58
orthocranial	58–63
hypsicranial	63+

This index may be used on the living head, and with the same values. The terms to be used are chamaecephalic, orthocephalic, etc., as with No. 1.

4. *Breadth-height index* $\frac{\text{basion-bregma height [4}a\text{]} \times 100}{\text{maximum cranial breadth [2]}}$

tapeinocranial	below 92
metriocranial	92–98
acrocranial	98+

[The three indices 1, 2, and 4, comparing each pair of the three dimensions, *length, breadth, height,* together give the dimensions of a skull viewed as a rectangular box. The *length-breadth* index suggests the shape as seen from above (norma verticalis); the

*As suggested by Martin, the suffix "*cranial*" is here employed to express the length-breadth index on the skull, and "*cephalic*" for the corresponding index on the living head. Thus, a head with an index of 78 is mesocephalic, while the same head, macerated and reduced to a skull, should have an index of 77 and be mesocranial.

** To be precise the upper limit of each class extends *up to* the lower one of the next above, but does not reach it. Thus, the class beginning at 75 extends up to the one beginning at 80, but ends at 79.99 +. [It is, however, more convenient, and more easily remembered to write these limits as here (75–80, etc.) and no confusion need arise if the actual state of the case is well understood.]

length-height, as seen from the side (norma lateralis); and the *breadth-height*, as seen from behind (norma occipitalis)].

5. *Calvarial height index* $\frac{\text{calvarial height [48]} \times 100}{\text{nasion-inion line [33]}}$

The calvarial height is to be taken from the craniogram; the nasion-inion line from either the same or by direct measurement.

6. *Bregma position index* $\frac{\text{nasion to foot of bregma perpendicular} \times 100}{\text{nasion-inion line [33]}}$

[The lesser the index the farther forward the bregma, and consequently the higher the position of the frontal bone. The upper measurement is taken from the *craniogram;* the nasion-inion line from either the same or by direct measurement].

7. *Sagittal cranial curvature index* $\frac{\text{nasion-inion line [33]} \times 100}{\text{sagittal cranial arc [22]}}$

8. *Transverse cranial curvature index* $\frac{\text{biauricular breadth [35]} \times 100}{\text{transverse cranial arc [23]}}$

9. *Transverse fronto-parietal index* $\frac{\text{least frontal breadth [5]} \times 100}{\text{maximum cranial breadth [3]}}$

stenometopic	below 60
metriometopic	66–69
eurymetopic	69+

10. *Indices showing the Relations of the Various Sagittal Arcs.*

(*a*) *Fronto-parietal index* $\frac{\text{parietal arc [40]} \times 100}{\text{frontal arc [39]}}$

(*b*) *Fronto-occipital index* $\frac{\text{occipital arc [41]} \times 100}{\text{frontal arc [39]}}$

(*c*) *Parieto-occipital index* $\frac{\text{occipital arc [41]} \times 100}{\text{parietal arc [40]}}$

(*d*) *Fronto-sagittal arc index* $\frac{\text{frontal arc [39]} \times 100}{\text{total sagittal arc [22]}}$

(*e*) *Parieto-sagittal arc index* $\frac{\text{parietal arc [40]} \times 100}{\text{total sagittal arc [22]}}$

(*f*) *Occipito-sagittal arc index* $\frac{\text{occipital arc [41]} \times 100}{\text{total sagittal arc [22]}}$

11. *Indices indicating the amount of curvature (bulging) of each of the three contour bones of the cranium.*

(*a*) *Frontal curvature index* $\frac{\text{frontal chord [42]} \times 100}{\text{frontal arc [39]}}$

(*b*) *Parietal curvature index* $\frac{\text{parietal chord [43]} \times 100}{\text{parietal arc [40]}}$

(*c*) *Occipital curvature index* $\frac{\text{occipital chord [44]} \times 100}{\text{occipital arc [41]}}$

12, 13. *Indices of the separate portions of the frontal and occipital arcs.*

The frontal and occipital arcs admit each of a separation into two parts, the proportions of which are of significance. The frontal arc is divided by the supraglabellare into a *pars glabellaris* and a *pars cerebralis:* the occipital is divided by the inion into an upper and a lower scale (*squama*). In each case the various measurements of arcs and chords may be compared by the use of indices and give details concerning the contour of the bones in question. Those which concern the forehead are of especial significance.

12. *Indices of the frontal curvature*

12(*a*) *Glabellar curvature index* $\frac{\text{chord of pars glabellaris } [g-sg] \times 100}{\text{arc of pars glabellaris}}$

[This gives the amount of projection (bulging) of the supra-orbital region, and is especially useful in comparing the Neandertal and other prehistoric types with the present species; also in the study of Australians, and other primitive races].

12(*b*) *Cerebral curvature index* $\frac{\text{chord of pars cerebralis } [sg-b] \times 100}{\text{arc of pars cerebralis}}$

12(*c*) *Glabello-cerebral index* $\frac{\text{chord of pars glabellaris } [g-sg] \times 100}{\text{chord of pars cerebralis } [sg-b]}$

13. *Indices of the occipital curvature*

13(*a*) *Upper scale curvature index* $\frac{\text{chord of upper scale } [l-i] \times 100}{\text{arc of upper scale}}$

13(*b*) *Lower scale curvature index* $\frac{\text{chord of lower scale } [i-o] \times 100}{\text{arc of lower scale}}$

13(*c*) *Upper and lower scale index (chords)*

$$\frac{\text{chord of lower scale } [i-o] \times 100}{\text{chord of upper scale } [l-i]}$$

13(*d*) *Upper and lower scale index (arcs)* $\frac{\text{arc of lower scale} \times 100}{\text{arc of upper scale}}$

[The two last indices give the relative position of the inion.]

14. *Index of the occipital foramen*

$$\frac{\text{breadth of foramen occipitale } [216] \times 100}{\text{length of foramen occipitale } [21a]}$$

[Like other indices, this gives the shape rather then the size. These indices may be classified as *narrow*, below 82; *average*, 82–86; and *broad*, from 86 on.]

II. INDICES OF THE FACE*

15. *Total facial index* $\frac{\text{nasion-gnathion line } [11] \times 100}{\text{bizygomatic breadth } [8]}$

* Cf. Marie Sawalischin, in Archiv f. Anthropologie, Bd. 8, 1909., pp. 298–307.

hypereury-prosopic	below 80
euryprosopic	80–85
mesoprosopic	85–90
leptoprosopic	90–95
hyperleptoprosopic	95+

[Various facial lengths, other than the one used here, have been employed by certain anthropometrists, such as the length from the ophryon, or the supra-orbitale, instead of the nasion. For the facial breadth, both here and in the next, Virchow used the zygomaxillare instead of the zygion, and made the breadth zm-zm, instead of zy-zy.]

16. *Superior facial index* $\frac{\text{nasion-prosthion line [12]} \times 100}{\text{bizygomatic breadth [8]}}$

hypereuryene	below 45
euryene	45–50
mesene	50–55
leptene	55–60
hyperleptene	60+

[The suffix "-ene," in the form -en, was first proposed by Martin in 1914 to distinguish between the adjectives used for the total face and the upper face. It is derived from an old Greek root, akin to the Sanskrit Ana-s, the mouth, and surviving only in a few adjectives, with the meaning of *Face;* ἠνος, προσ-ηνής. Whether it is better thus to differentiate the two facial indices, or to use the same words, compounded with "-prosopic," stating carefully which index is meant, or relying upon the numerical differences of the two groups of indices, must be left for usage to decide.]

17. *Zygomatico-malar (jugal) index* $\frac{\text{zygomaxillary breadth [37]} \times 100}{\text{bizygomatic breadth [8]}}$

18. *Zygomatico-frontal index* $\frac{\text{least frontal breadth [5]} \times 100}{\text{bizygomatic breadth [8]}}$

19. *Zygomatico-mandibular index* $\frac{\text{bigonial breadth [26]} \times 100}{\text{bizygomatic breadth [8]}}$

20. *Interorbital index* $\frac{\text{anterior interorbital breadth } [mf - mf] \times 100}{\text{outer biorbital breadth } [fmt - fmt]36}$

[For the measurement between the eyes the maxillofrontale is now generally chosen, that known as the *anterior biorbital breadth.* (Measurement No. 15, as modified.) This index is therefore sometimes designated the "Anterior interorbital index."]

21. *Orbital index* $\frac{\text{orbital height [at rt. angles to orb. breadth]} \times 100}{\text{orbital breadth [16 modified]}}$

[The orbital breadth of the Monaco Agreement employs the dacryon instead of the maxillofrontale, but modern usage prefers the latter. The difference would be so very slight that it would not seem necessary to calculate two indices.]

chamaeconch	below 76
mesoconch	76–85
hypsiconch	85+

22. *Nasal index* $\frac{\text{nasal breadth [14]} \times 100}{\text{nasal length [13, } n - ns\text{]}}$

leptorrhine	below 47
mesorrhine	47–51
chamaerrhine	51–58
hyperchamaerrhine	58+

[The nasal spine is to be located laterally (cf. *nasospinale*, under Landmarks; also the description of No. 13)].

23. *Maxillo-alveolar index* $\frac{\text{maxillo-alveolar breadth [18]} \times 100}{\text{maxillo-alveolar length [18 bis]}}$

dolichuranic	below 110
mesuranic	110–115
brachyuranic	115+

24. *Palatal index* $\frac{\text{palatal breadth [19}b\text{]} \times 100}{\text{palatal length [19}a\text{]}}$

leptostaphyline	below 80
mesostaphyline	80–85
brachystaphyline	85+

25. *Mandibular index* $\frac{\text{mandibular length [46]} \times 100}{\text{bicondylar breadth [25]}}$

26. *Ramus index* $\frac{\text{breadth of ramus [28}a\text{]} \times 100}{\text{length of ramus [27]}}$

27. *Dental index* $\frac{\text{molar length} \times 100}{\text{nasion-basion line [9]}}$

[The *molar length* is that of the two bicuspids plus the three molars of the upper jaw. The measure is taken from the anterior (mesial) side of the first bicuspid to the posterior (lateral) side of the third molar].

microdont	below 42
mesodont	42–44
megadont	44+

III. INDICES SHOWING RELATIONS BETWEEN CRANIUM AND FACE

28. *Longitudinal cranio-facial index* $\frac{\text{basion-prosthion line [10]} \times 100}{\text{maximum cranial length [1]}}$

29. *Transverse cranio-facial index* $\frac{\text{bizygomatic breadth [8]} \times 100}{\text{maximum cranial breadth [2]}}$

30. *Vertical cranio-facial index* $\frac{\text{nasion-prosthion line [12]} \times 100}{\text{basion-bregma line [4a]}}$

IV. INDICES EMPLOYING THE LINES DERIVED FROM A MEDIAN SAGITTAL CRANIOGRAM

Since certain lines and linear measurements, as stated above, may be taken either direct or by means of the median sagittal craniogram, necessitating their appearance in two places, so is also the case with the indices constructed from them; and, as in the former case, certain indices are here repeated, always with their old numbers.

2. *Length-height index* $\frac{\text{basion-bregma height [4a]} \times 100}{\text{maximum cranial length [1]}}$

[For classification of the resulting indices, see above.]

5. *Calvarial height index* $\frac{\text{calvarial height [48]} \times 100}{\text{nasion-inion line [33]}}$

[The calvarial height is to be taken from the craniogram; the nasion-inion line from either the same source, or by direct measurement].

6. *Bregma position index* $\frac{\text{nasion to foot of bregma perpendicular} \times 100}{\text{nasion-inion line}}$

[As in the last two, the numerator is measured upon the craniogram; the denominator by either method. The lesser the value of the index the further forward the bregma position, and consequently the more erect the position of the frontal bone].

28. *Longitudinal cranio-facial index* $\frac{\text{basion-prosthion line [10]} \times 100}{\text{maximum cranial length [1]}}$

30. *Vertical cranio-facial index* $\frac{\text{nasion-prosthion line [12]} \times 100}{\text{basion-bregma height [4a]}}$

31. *Lambda calvarial height index* $\frac{\text{lambda calvarial height [49]} \times 100}{\text{nasion-lambda line [46]}}$

[As in the last, both measures may be taken from the craniogram; or the nasion-lambda may be measured direct].

32. *Frontal perpendicular index* $\frac{\text{frontal perpendicular [51]} \times 100}{\text{frontal chord [42]}}$

[The lower this index the flatter the forehead. This has nothing to do with the *position* of the contour line, i.e., whether the forehead is "high" or "retreating," but refers solely to the shape of the contour, however placed with reference to the entire skull].

33. *Parietal perpendicular index* $\frac{\text{parietal perpendicular [52]} \times 100}{\text{parietal chord [43]}}$

[A low index signifies a flat contour].

34. *Occipital perpendicular index* $\frac{\text{occipital perpendicular [53]} \times 100}{\text{occipital chord [44]}}$

[A low index signifies a flat contour].

V. INDICES OF WEIGHT AND CAPACITY

[Various indices of weight and capacity have been employed, but comparisons can be made only in the case of skulls in about the same condition with respect to dryness, and where nothing of the bone substance has been lost through decay or weathering. The following are some of the most important, and are suggestive of further study along this line].

35. *Calvario-cerebral weight index*

$$\frac{\text{weight of skull, without mandible} \times 100}{\text{cranial capacity}}$$

[Here, as elsewhere when capacity is compared with weight, the weight must be in grams, the capacity in cubic centimeters]

36. *Mandibulo-cerebral weight index* $\dfrac{\text{weight of mandible} \times 100}{\text{cranial capacity}}$

[Here, and in all indices involving the weight of the mandible, as in the two below, the mandible is supposed to have a full complement of teeth. Some operators have a lot of odd teeth and find a corresponding tooth for each one gone, which is to be weighed with the jaw. Others add an average weight (1.25 g.) for each tooth missing].

37. *Calvario-mandibular weight index* $\dfrac{\text{weight of mandible} \times 100}{\text{weight of skull alone}}$

38. *Femero-cranial weight index* $\dfrac{\text{weight of skull without mandible} \times 100}{\text{weight of the two femora}}$

Angles

Angles.—The great majority of the cranial angles in use, either now or formerly, lie in the median sagittal plane. These, in the early practice, were rendered available for study by the drastic method of sawing the skull in two along the median plane, a practice which had the advantage of laying bare internal as well as external proportions, yet presented the disadvantages of rendering the specimen practically useless for many other data, especially breadth measures, involving points upon both moieties, and measured across the bisected skull. Prof. Huxley, however, at one time advocated this procedure so strongly that he declared that the time would come when it would be considered a disgrace for an anthropological collection to possess as much as a single skull that had not been thus treated.

Fortunately for the science of anthropometry the introduction of the diagraph, with the possibility of obtaining an accurate profile tracing of the outer contour, without injury to the skull itself, has rendered available the study of all external curves and of angles involving only external parts, without recourse to bisection; while, by means of recently devised instruments, certain important internal landmarks may be reached and located through the occipital foramen without injuring the specimen. Furthermore, the development of various forms of goniometer, and the establishment of a fixed horizontal, and other means for a precise orientation, have introduced methods of measuring many of the most essential angles directly upon the skull.

There is thus usually left to the operator in determining a given angle, a choice of several methods, but where a craniogram is available it will often be found very convenient and practical to draw the angles to be measured upon it, and then measure them on the paper by means of a transparent protractor. This procedure is so very available, in fact, that it offers a serious temptation to the investigator to try any angles that suggest themselves, with the hope that they may prove useful or even reveal some unexpected and significant relation that has escaped the eye.

The following angles have either already been extensively used with success in showing important difference, or are believed to have some chance of success in the future. As some angular measurements are very old, older in fact than any linear measurements, the most of these have now become classical by use, and are of first importance.

1. *Metopic or frontal profile angle.* This is the angle of inclination of the nasion-metopion line to the FH, and is best measured direct by the stationary goniometer. The metopion, the point in the median line crossed by the line connecting the two frontal eminences, is first ascertained as accurately as possible, and marked on the skull surface by a pencil. Then, with the skull oriented exactly on the FH, the two points of the goniometer are placed, the one on the nasion, the other on the metopion, and the angle read off in the usual way.

The exact apex or center of the two frontal eminences is more easily ascertained by the finger, rubbed over the surface, than by the eye; or when, as in an especially smooth forehead, even this method is insufficient or uncertain, the point in the median line exactly one-third of the distance from nasion to bregma is taken as the metopion. GO.

2. *Frontal angle of Schwalbe.* A somewhat more practical frontal profile, readily drawn and measured upon a craniogram, and serving the same purpose of the previous one, is that devised by G. Schwalbe and used first in his studies of *Pithecanthropus erectus.**

As first used this angle was formed by the glabella-inion line with one drawn upward from the glabella and tangent to the most projecting point in the frontal profile curve; but in his later use of this Schwalbe substituted nasion for glabella, and the angle now used is fr-n-i, *fr* being the indefinite free end of the frontal tangent. CG.

3. *Frontal inclination angle* (= "Bregma angle" of Schwalbe). This has the advantage over the previous angle in the accuracy of the points

* Zeitschr. für Morphol. und Anthropol. Bd. I, 1899, p. 142.

involved, but does not measure quite the same thing, and cannot be substituted for it. It measures the inclination of the frontal chord (the line nasion-bregma) to the nasion-inion line. Schwalbe, who first employed it under the name of the *Bregma angle*, measured it upon a craniogram, but it may equally well be measured direct by first setting the skull upon the nasion-inion, instead of the FH, as a horizontal, and then measuring with the goniometer, one foot each upon nasion and bregma. CG or GO.

4. *Occipital inclination angle* [="Lambda angle" of Schwalbe]. The inclination of the lambda-inion to the nasion-inion line. This is best drawn upon the craniogram, as is done with the Frontal inclination angle, its counterpart at the other end of the nasion-inion. These two angles, which fix definitely the position of the frontal and occipital bones, respectively, were called by G. Schwalbe, who first proposed them, the "bregma" and "lambda" angles, evidently forgetting for the moment that angles are usually named from the point that forms their apex. He also used the glabella-inion, instead of nasion-inion, in accordance with the usage of the time.*

As with the frontal inclination angle, this may also be measured upon a skull, set upon the FH, by means of the stationary goniometer, the two points of which rest upon lambda and inion. CG or GO.

5. *Facial profile angle* [The modern equivalent of the facial angle of Camper]. The inclination of the nasion-prosthion line to the FH. Use as prosthion the most projecting point of the alveolar border in the median line and measure with the stationary goniometer. In a skull with a seriously damaged alveolar border this angle cannot be taken. The angles have the following values:

hyperprognathous	below 70°
prognathous	70°–80°
mesognathous	80°–85°
orthognathous	85°–93°
hyperorthognathous	93° +

This angle gives the inclination of the line used in calculating the superior facial index (index No. 16) and as it includes the slant of the entire upper face, it is very important, especially as a racial criterion. It was about this angle, roughly estimated, and very imperfectly designated, that was used by Petrus Camper as his famous *Facial Angle*, which yielded such definite results as a racial criterion, and may be considered the beginning of the modern science of anthropometry. GO.

6. *Nasal profile angle*. Similar to the last, but with a shorter line subtending the angle, that of the *nasal* length, instead of the superior

* For the frontal inclination angle cf. Zeitschr. für Morphol. und Anthropol. Bd. I, 1899. p. 142. For the occipital inclination angle cf. Zeitschr. für Morphol und Anthropol. Sonderheft, 1906. p. 20.

facial. It is measured in an oriented skull with the stationary goniometer, the two points of the instrument resting on nasion and nasospinale. This latter point is determined by drawing a line across the lower border of the nasal aperture, tangent to the two lateral curves at their lowest points, and taking the point in this line where it crosses the median line. This nasio-nasospinale line is nearly as long as the one used in the previous case (nasion-prosthion), so that in practice the same

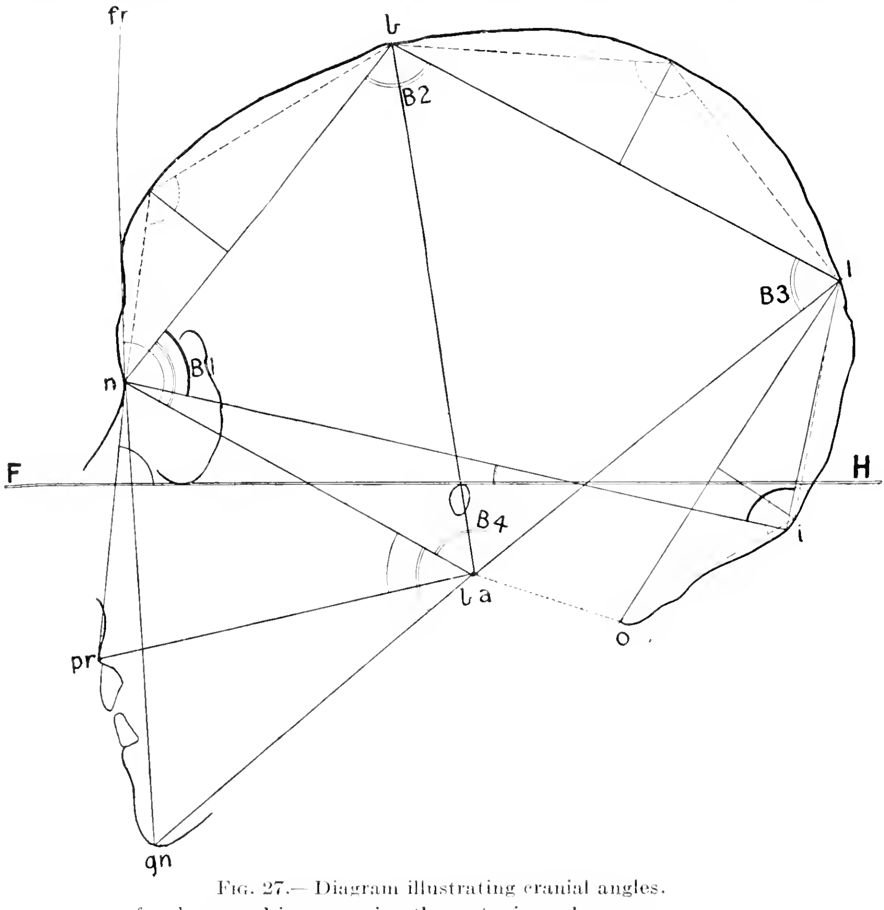

Fig. 27.—Diagram illustrating cranial angles.
n-fr, plane used in measuring the metopic angle.
fr-n-i, frontal angle of Schwalbe.
b-n-i, frontal inclination angle (bregma angle of Schwalbe).
l-i-n, occipital inclination angle (lambda angle of Schwalbe).
n-ba-pr, superior facial length angle.
n-ba-pr (as a triangle), superior facial triangle.
n-b-l-ba, cranial quadrilateral.

classification has been used, with the same values; it has the obvious advantage of eliminating all uncertainty concerning the often poorly defined alveolar border, especially when it is brought forward because of projecting teeth (alveolar prognathism), and thus exaggerates the prognathism of the skull as a whole. Should this angle be actually substituted for the previous one as the definite measure of the prognathism of a skull, it will probably be found advisable to reduce the values of the classes in the classification, to correspond with the reduction in the size of the angles. GO.

7. *Alveolar profile angle.* The inclination of the profile of the alveolar region, measured from nasospinale to prosthion (its most projecting point). This angle can be measured only on skulls with complete alveolar region in the median line, and is taken with the stationary goniometer upon an oriented skull, as in the two previous cases. This seems hardly a practical angle to use, although it is generally recommended, since it is too small an angle to take accurately, and since it is too easily affected by varying degrees of projection of the teeth, quite an individual peculiarity and not racial. GO.

8. *Profile angle of the nasal roof* (the nasal bones). Inclination of the nasion-rhinion line, measured in the same way as the last, the two points of the goniometer resting upon the termini of the line in question. To be used only in skulls in which the nasal bones are complete. GO.

9. *Calvarial base angle.* The inclination of the nasion-inion line (= calvarial base) to the FH. This is readily measured with the stationary goniometer on a skull placed upon the FH in a cubic craniophore. The craniophore is placed so that the norma occipitalis is beneath, and the norma verticalis towards the instrument. The two points rest respectively upon nasion and inion, and the angle shown is the complement of the one sought.

The knowledge of the usual values of this angle and of Schwalbe's frontal angle (2) will allow one to place a fragmentary cranium upon approximately its proper position, and save one from making such erroneous conclusions concerning the set of the head and the slope of the forehead in life, as was most unfortunately done in the case of the supposed *Diprothomo platensis* of Ameghino. Fragmentary skulls, consisting of calvarium alone, and this often badly broken, are so frequently found that a knowledge of this angle, giving the usual relationship of the nasion-inion line, is extremely useful.*

10. *Inclination of the occipital foramen.* This is naturally the inclination which the plane placed across the foramen, and including both basion and opisthion, makes with the plane of the FH, *i.e.*, a dihedral angle, but in a symmetrical skull it should have the same value as the angle made

* For the studies of G. Schwalbe concerning the proper orientation of a skull fragment, based upon the usual relations of the nasion-inion and glabella-lambda lines, cf. Zeitschrift für Morphol und Anthropol. Sonderheft, 1906. Das Schädelfragment von Brüx, and especially the diagram on p. 137, where the usual angle lambda-glabella-inion is given as 20°, and the angle glabella-inion FH as 15°. The author, like the rest of the world, was then using the glabella, instead of the nasion for all such data (*e.g.*, the calvarial base), as is here the case. For the critical study of *Diprothomo* by the same author cf. Zeitschr. für Morphol. und Anthropol., Bd. XIII, 1910–1911, pp. 209–258.

by the line basion-opisthion and the median line of the FH, which is always the line meant in a craniogram involving this horizontal.

As most forms of craniophore use the occipital foramen to fasten the clamp into which holds the skull, either basion or opisthion or both are not available, a special form of craniophore is devised which takes hold of the skull elsewhere. A thin strip of metal is then attached to both basion or opisthion by wax, plastilena, or some similar substance and the inclination of this strip taken with the goniometer. When the opisthion is higher than the basion the angle made with the FH opens backwards and is marked with a + sign; when the basion is higher, the angle opens forwards, and is marked with a − sign.

11. *Frontal curvature angle.*
12. *Parietal curvature angle.*
13. *Occipital curvature angle.*

These angles, all constructed in the same way upon the craniogram, show with considerable precision the shape of the three contour bones of the cranium, as they appear in the median line. In each case the longest perpendicular is erected upon the chord of the bone in question (lines 51, 52, and 53 above), and lines drawn from where this perpendicular comes in contact with the contour curve to each end of the chord. The angle thus formed is the angle sought. The greater the angle the flatter the bone. CG.

14. *Occipital flexional angle.*—This angle, which shows the amount of bend, or flexion of the two parts of the occipital scale, with apex at the inion, is drawn upon the craniogram, by the lines l-i and i-o, and measured by the protractor. CG.

15. *Superior facial length angle.*—The angle formed at the basion, by the lines nasion-basion and prosthion-basion (9 and 10), and subtending the superior facial line. Drawn upon the craniogram, and measured by the protractor. CG.

16. *Facial length angle.*—Similar to the last, but using the line gnathion-basion (34), instead of prosthion-basion, and thus subtending the total, instead of the superior, facial length. Only to be done in skulls with a good mandible, which is set in the proper position, either by a spring or by plastilena, before making the craniogram. CG.

Aside from angles, certain triangles or higher polygons are readily drawn upon a craniogram, or are constructed (like the triangle n-ba-pr) as a result of the preceding work. The various angles of these may be of some value, yet their further study falls dangerously near the empirical method above mentioned. However, there may be mentioned in this connection one triangle and one quadrilateral, whose position makes them more or less fundamental in describing the shape of a given skull.

A. The *Superior facial triangle* (n-ba-pr).—This follows and approximately defines the nasal fossa, being bounded by the cranio-basal length line, and the lines of length and breadth of the superior face. Whether the angles which have their apices at n and pr are of especial value is not known, but the third angle, the apex of which is at ba, is already listed above, and serves to measure the length of the superior face.

B. The *Cranial quadrilateral* (n-b-l-ba).—This figure, more than any other, especially with the cranial base as one of its sides, serves to define

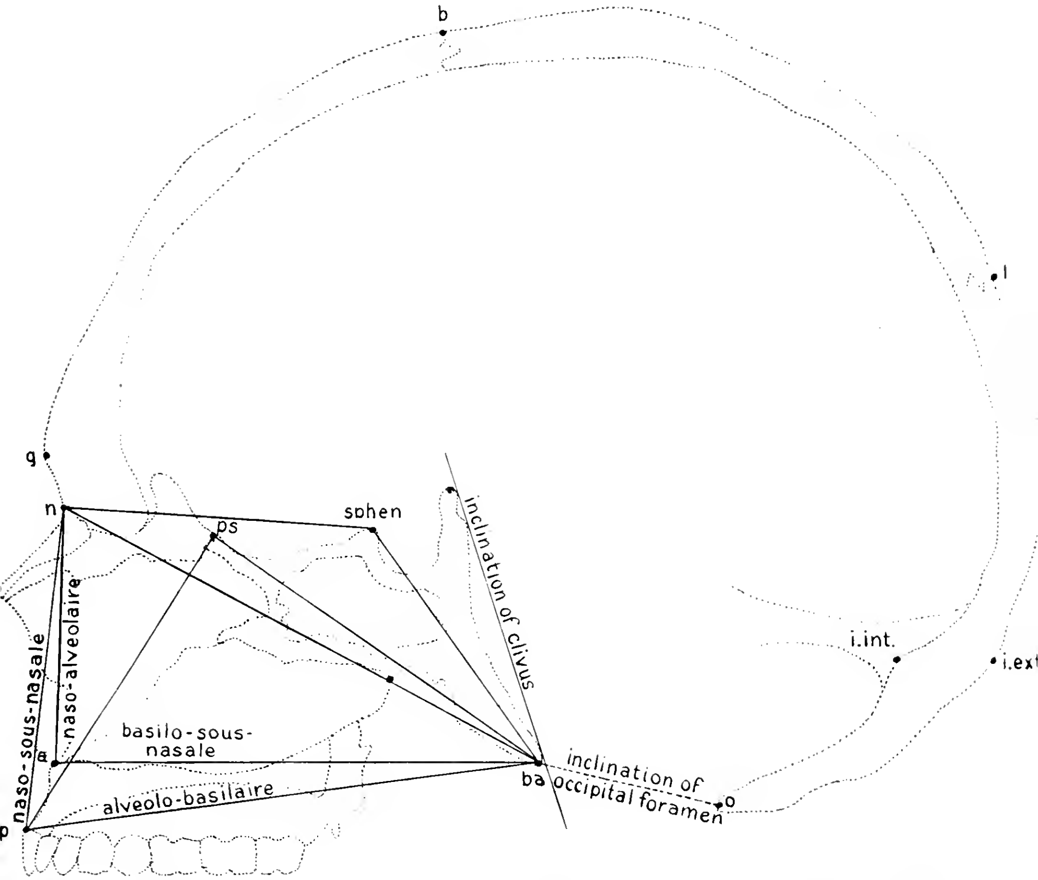

FIG. 28.—Important angles shown on a sawn skull, illustrating an old method of study; based upon several drawings of Topinard. Certain well-known lines are given their earlier French nomenclature to facilitate the reading of French texts of the period of Broca and Topinard.

n–sphen–ba, the Sphenoidal angle of Welcker.
n–ba, the cranio-basal length, the "cranial base line."
n–ba–pr, the facial triangle of Vogt.
n–ba–a, the facial triangle of Welcker.

The naso-basal angles of Vogt and Welcker, respectively, were used by these two men. Vogt used the angle n–ba–pr, and Welcker the angle n–ba–a. The two inions, external and internal, are incidentally shown in this figure.

the profile of the entire cranium. Thus far it is not known to have been used, but from its appearance, embracing the entire cranial contour, it would seem to have some value, which future work may prove. Its angles at n and l subtend the basion-bregma height; the angles at b and ba subtend the nasion-inion (B_1–B_4). It is presented here merely as a suggestion.

II. THE VERTEBRAL COLUMN, WITH THE RIBS AND STERNUM

The Vertebral Column, with the Ribs and Sternum.—One of the most frequently emphasized differences between man and the apes is that of the degree of forward curvature of the vertebral column in the lumbar region (*lordosis*). This curve which, in its extreme form, is characteristic of the human back, is displayed to a much lesser degree in the Simiidæ, and in the gibbons (*Hylobates*), the lowest of the family, is but slightly indicated.

It is thus generally considered, and with much probability, that this lumbar curve has been gradual attainment in the evolution of man, and that, in all probability, the curve would be found to be less in the lower races, and thus serve as a racial criterion.

The ideal and only complete method of studying this and the other curves of the vertebral column is by means of accurately made sagittal sections taken through frozen bodies, but owing to the obvious difficulties, this had been done in only a few cases, and includes only representatives of races of higher culture. Much can be done, however, by the study of the separate vertebræ, since the character of the curve is conditioned largely by the proportions of the bodies of the vertebræ involved. By measuring the antero-posterior thickness, of the lumbar centra in the median line, both dorsally and ventrally, and then comparing the two, it is found that these parts are wedge-shaped, the most anterior one slightly, increasing gradually to the fifth, in which this character is the most pronounced. It is to this that the lumbar curve is largely due, and thus the degree of curvature may be ascertained by obtaining the above measurements of the vertebral centra.

As a sufficiently exact measurement is difficult or impossible, and as the differences between the dorsal and ventral measures of single vertebræ are but slight, Turner, who first proposed this method, obtained more accurate figures by adding together the measurements obtained from twelve individual spinal columns, and comparing the sums.* Thus, the ventral measure of the 12 fourth lumbar vertebræ was 336 mm. while the dorsal measures of the same parts was only 313. In the 12 fifth lumbar vertebræ the corresponding numbers were 337 and 281, a more pronounced difference, since the ventral measures were practically identical,

* TURNER, SIR WILLIAM: Report on the Human Crania and Other Bones of the Skeletons Collected During the Voyage of H. M. S. Challenger in the years 1873–76. Part II. The bones of the Skeleton, publ. in 1886 in the Reports of the Challenger Expedition, *Zoology*, Vol. XVI, pp. 1–136.

while there was a marked disparity in the dorsal one, indicating a more definite wedge for the fifth than for the fourth. To get the average difference for a single vertebra these figures are divided by 12, giving for the fourth lumbar vertebra the figures 28 : 26 mm., and for the fifth, 28 : 23.4.

The amount of curvature in a single spine can be indicated by taking the above measurements, adding together the five dorsal thicknesses, and comparing the sum with that obtained by adding the five ventral ones. The result can be best obtained in the form of a *General lumbar index*, thus:

39. *General lumbar index*

$$\frac{\text{dorsal vertical diam. of lumb. vert. I} - \text{V} \times 100}{\text{ventral vertical diam. of lumb. vert. I} - \text{V}}$$

The values from this index may be classified as follows:

* curtorhachic	(= convex spine)	below 98
orthorhachic	(= straight spine)	98–102
coelorhachic	(= hollow spine)	102+

The *Special lumbar index* for a single vertebra may be obtained in a similar way by dividing the dorsal by the ventral antero-posterior diameter (thickness), and the general index may be calculated from the five results by obtaining the mean, or average, of all five.

40. *Special lumbar index*

$$\frac{\text{dorsal vert. diam. of vert. I, II, III, etc.} \times 100}{\text{ventral vert. diam. of same vertebra}}$$

The special index of a given vertebra in a number of cases may be averaged as is done in any other such data, and the results compared as racial criteria. Thus Turner presents the following table.

	12 Europeans	5 Australians	2 Andamanese	3 Negroes	3 Hawaiians
1st lumb. vert.	106.8	114.4	111.3	108.8	114.6
2d lumb. vert.	101.5	112.3	105.6	104.2	108.0
3d lumb. vert.	95.4	108.0	102.0	100.0	108.2
4th lumb. vert.	93.0	103.7	91.8	93.0	101.5
5th lumb. vert.	83.6	91.4	84.2	89.0	87.7
Mean general lumbar index	96.0	106.0 (nearly)	99.0 (nearly)	99.0	104.0

From this table there will be noted the marked change of shape of the vertebral bodies from the first to the fifth. In the first and second the

* Gk. ῥάχις, a spine; κυρτός, arched, convex; ὀρθός, straight; κοῖλος, hollow. Turner's spelling retained the Greek form, *kurtorhachic*, *coilorhachic*, as also in his compounds with -kerkic (cercic) below, but the spelling given here is more in accordance with modern usage.

bodies are wedge-shaped, with the lesser thickness (the edge) pointing backwards (dorsally); the third is about square, *i.e.*, the anterior and posterior surfaces are nearly parallel, and in the negro absolutely so; while in the fourth and fifth the wedge is turned around, with the edge pointing forwards (ventrally). Cunningham,* who investigated a much larger number of European skeletons than did Turner (76), found the index for the first lumbar vertebra to be 106.1, and for the fifth 81.6, with the general index, 95.8, practically the same as the latter author. For the negro he obtained a general index of 105.4, and for the Andamanese 104.8, both considerably larger than the results of Turner.

Studies of the vertebral column, calculated to bring out the wedge-shaped character of the vertebral bodies, and incidentally the curves, have been undertaken by Hasebe,† who has carried out the bulk of his work upon Japanese material, but has compared his results with the studies of others upon other races. Among his tables, which are both numerous and extensive, he includes such measures as the ventral and dorsal vertical measures of the vertebral bodies, the transverse and sagittal diameters of the same, with special studies of certain important vertebræ, as the atlas, the epistropheus, and the sacrum.

The volumetric measures of the vertebral column, both as a whole, and in its separate groups, compared in various ways, have been employed by Wetzel,‡ in a study of the vertebral column of the native Australians. These volumes are obtained by means of water replacement. He finds the average volume, both of entire vertebral columns, and of separate vertebræ, in 8 Australians, 6 Europeans, and 2 negroes, besides the same data for the vertebral column of an adult orang-utan, for comparison. The average volume of the entire column, including the sacrum, together with the maximum and minimum among the individual studies was found as follows:

Volume of the Entire Vertebral Column, Including the Sacrum
(in cubic centimeters)

<table>
<tr><th>Name of race</th><th>Average volume</th><th>Maximum</th><th>Minimum</th></tr>
<tr><td>Australians (8)</td><td>521</td><td>687</td><td>450</td></tr>
<tr><td>Europeans (6)</td><td>774</td><td>916</td><td>631</td></tr>
<tr><td>Negroes (2)</td><td>873</td><td>890</td><td>857</td></tr>
<tr><td>Orang-utan (1)</td><td>546</td><td colspan="2">546</td></tr>
</table>

The average volume of single vertebræ is taken by measuring all of one group together and dividing by the number of the group; thus, the

* The Lumbar Curve in Man and the Apes; Dublin, 1886.

† Die Wirbelsäule der Japaner. Zeitschr. für Morphol. und Anthropol. Bd. XV, 1912, pp. 259–380.

‡ Die Wirbelsäule der Australier. Zeitschr. für Morphol. und Anthropol., Bd. XII, 1909, pp. 313–340.

volume of the cervical vertebræ of a given skeleton is divided by 7, that of the thoracic vertebræ by 12, and of the lumbar vertebræ by 5. This average number for a single vertebra of a given group is then averaged for all the individuals of a given race, with the following results:

TABLE OF THE AVERAGE VOLUMES OF SINGLE VERTEBRÆ
(in cubic centimeters)

Name of race	Average of a cervical vertebra	Average of a thoracic vertebra	Average of a lumbar vertebra	All together, one of each
Australians (8)	7.4	16.1	33.7	57.2
Europeans (6)	10.4	25.1	45.6	81.1
Negroes (2)	13.2	27.9	54.0	95.1
Orang-utan (1)	11.5	18.1	34.7	64.3

The volume of the four separate groups (including the sacrum) as compared with the total volume of the entire column, is of interest. Here the total volume is taken as 1000, and the components are given as proportionate parts of it. In other words this table is constructed by means of the following Volumetric group index, No. 3. Total volume of vert. column × 100 Volumes of each group.

TABLE OF PROPORTIONATE VOLUMES OF THE GROUPS OF VERTEBRÆ
(the total volume = 1000)

	Cervical	Thoracic	Lumbar	Sacrum
Australian (male) (4)	103	378	319	200
Australian (female) (4)	96	361	315	233
European (male) (5)	96	397	295	213
European (female) (1)	85	339	299	278
Negro (male) (2)	106	385	309	201

In the above table the separation of the sexes shows certain interesting sexual differences, notably that of the volume of the sacrum, which is the greater in the female. This peculiarity is better brought out in the next table, which compares the volume of the sacrum with that of all the rest of the column, the total volume being considered as 1000, as in the other case.

TABLE SHOWING THE RELATIVE VOLUME OF SACRUM AS COMPARED WITH THE PRE-SACRAL VERTEBRAL COLUMN
(The first figure is that of the sacrum)

Australian (male)	200 : 800
Australian (female)	235 : 772
European (male)	213 : 787
European (female)	278 : 723
Negro (male)	201 : 800

Very little has as yet been done with the anthropometry of the ribs and sternum. The curvature of the ribs, connected as it is with the capacity of the chest and the relative lung capacity, is in part an individual character, but is undoubtedly in part also racial. This character has been studied thus far mainly in the living by means of thoracic measurements. A comparison of the ribs and sternum of such prehistoric human species as *Homo neandertalensis*, with the same parts of modern man should show us along what lines to look for racial differences in the bones themselves, and in this connection it is interesting to note that the ribs of this early species were less rounded in curvature than in modern man, indicating a cylindrical, rather than a flat, chest. This man was rather short in stature (1550–1650 mm.), with an enormously large head set well forward upon a short, massive neck. The thorax was cylindrical and very capacious, and the intercostal muscles were extremely well-developed. The ribs were themselves rather cylindrical than flat, giving a distinct triangular cross-section.*

III. SHOULDER-GIRDLE

Scapula

1. LINEAR MEASUREMENTS

1. *Maximum length* (morphologically the *breadth* †) [CD]; the distance between the most projecting points of the anterior (superior) and posterior (inferior) angles.

2. *Maximum breadth* (morphologically the length†) [BK]; from the middle of the lower border of the articular surface of the glenoid fossa to the terminus of the spinal axis [No. 3] upon the vertebral border.

3. *Spinal axis* [BA]; from the center of the glenoid fossa to the point where the prolonged lower edge of the spine intersects the vertebral border.

4. *Length of the spine* [BE]; from the last described point [B], to the most distant point upon the acromion process.

5. *Length of the supra-spinous line* [BC]; from the point [B] to the anterior angle.

*Boule: L'homme fossile de la Chapelleaux-Saints; Annales de Paleontologie, T. VI, 1911; pp. 113–115.

Schwalbe, G.: Kritische Besprechung von Boule's Werk; L'homme fossile, etc., mit eigenen Untersuchungen. Zeitschr. für Morphol. und Anthropol., Bd. XVI, 1914; p. 565+.

† The scapula of man, and to a lesser degree that of the other Primates, is spread out antero-posteriorly far in excess of that of most other mammals, mainly because of the excessive lengthening in this direction of the infra-spinous portion of the blade. If comparison be made with other scapulæ, e.g., cat, horse, rat, which show the more usual shape it is at once apparent that the *length* runs in the same direction as the spine, and the *breadth* at right angles to it, across both fossæ.

6. *Length of the infra-spinous line* [BD]; from the point [B] to the posterior angle.

7. *Antero-posterior (vertical) diameter of the glenoid fossa;* taken across the lip, parallel to the axis of the body.

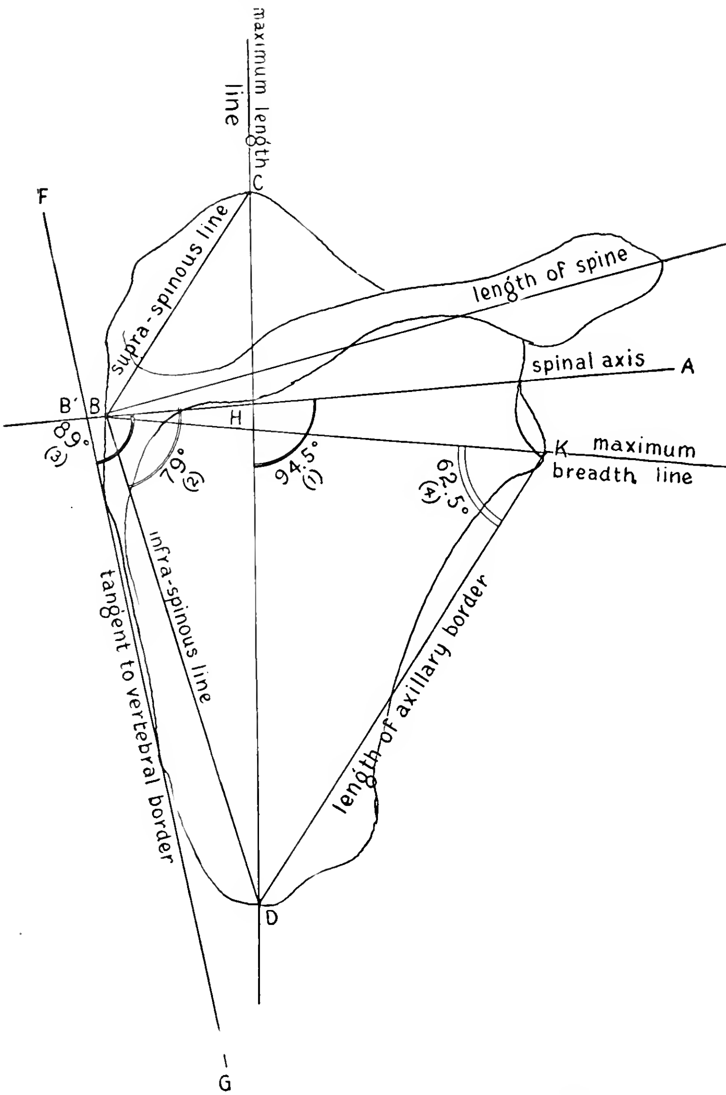

Fig. 29.—Right scapula, showing measurements and angles.

Spinal axis angle, AHD (1)
Infraspinous angle, ABD (2)
Vertebral border angle ABG (3)
Axillo-spinal angle, BKD (4)

8. *Dorso-ventral (transverse) diameter of the glenoid fossa;* measured in the same way, but at right angles to the preceding.

9. *Length of axillary border* [KD]; distance between the middle of the lower border of the glenoid fossa, and the posterior angle.

II. INDICES

1. *Scapular index* [2 : 1] $\frac{\text{maximum breadth} \times 100}{\text{maximum length}}$

2. *Supra-spinous index* [5 : 1] $\frac{\text{length; supra-spinous line} \times 100}{\text{maximum length}}$

3. *Infra-spinous index* [6 : 1] $\frac{\text{length; infra-spinous line} \times 100}{\text{maximum length}}$

4. *Axillary index* [9 : 1] $\frac{\text{axillary length} \times 100}{\text{maximum length}}$

5. *Fossorial index* [5 : 6] $\frac{\text{length; supra-spinous line} \times 100}{\text{length; infra-spinous line}}$

6. *Glenoid index* [8 : 7] $\frac{\text{transverse diameter, glenoid fossa} \times 100}{\text{vertical diameter, glenoid fossa}}$

III. ANGLES

1. *Spinal axis angle* [AHD]; made by the intersection of the spinal axis with the maximum length line.

2. *Infra-spinous angle* [ABD]; made by the intersection of the infra-spinous line (prolonged) and the spinal axis.

3. *Vertebral border angle* [ABG]; the angle between a line drawn tangent to the vertebral border and the spinal axis.

4. *Axillo-spinal angle* [BKD]; the angle made by the line of the axillary border length and the line of maximum breadth, meeting at the point [K] in the diagram.

The measurement of all of these angles can be best effected by the use of knitting needles, fastened directly upon the bone by wax or plastillna, and thus defining the lines. The angles are read off by a transparent protractor.

IV.—Table of Scapular Measurements*

Character	Maori (1)		Europ. (200)	French (73)	Austral. (6)	Senoi		Egyptian
	r	l				r	l	
Max. length....	145.0	142.0	155.0	168.0	154.5	152.0	137	
Max. breadth. ..	95.0	95.0	101.4	105.9	97.3	97.0	87	98.0
Supra-spin.......	59.0	55.0						
Infra-spin.......	109.0	106.0	113.6	124.3	113.6	103.0	95	110.0
Scap. index......	65.5	66.9	62.5	.....	63.0			
					64.9	72.5	...	65.9
Foss. index......	54.1	51.9						

* The above results are those of various authors, as found in Mollison (1908) and Martin (1914, pp. 977–978). The Europeans were studied by Flower and Garson (1880), the French by Livon (1879), and the Australians by Turner (1886). As elsewhere, the numbers of individuals studied in each case are given in parenthesis following the name of the race.

Clavicle

I. MEASUREMENTS

1. *Maximum length;** taken with the osteometric board.
2. *Girth;* taken at the middle of the shaft.
3. *The two angles of curvature;* These are taken upon the dioptograph tracing of the contour of the bone from above, oriented as this is done by having the two borders of the acromial third in the same plane, horizontally placed.

The middle axis of the bone is traced, following the curves, and beginning and ending in the center of the two ends; the points where the line attains the farthest point anteriorly and posteriorly are then

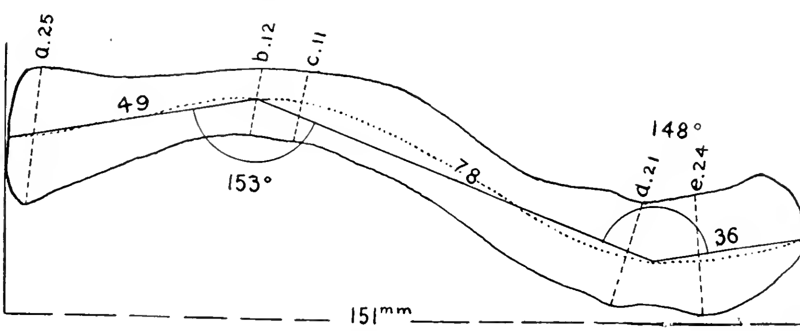

FIG. 30.—Right clavicle, from above, showing measurements. This figure is based upon several by Parsons, and represents the average measurements obtained from 70 English males.

marked, and lines drawn, connecting these with the middle of the two ends and with each other. These form a medial angle, projecting forward and a lateral, projecting backward. These can be measured with a protractor. Added together they form the "index of curvature." These may be directly compared.

4. *Breadths,* taken from the dioptograph tracing; Parsons uses *five* of these; at the two ends, at the inner angle, at the narrowest place, and at the conoid tubercle.

* PARSONS: *Engl. Journ. Anat.*, 1917, found the average length of English clavicles, taken from the lower and lower middle classes to be:

males, right (70)	151 mm.
males, left (83)	153
females, right (65)	138
females, left (64)	138

The above were separate clavicles, taken at random; when the two clavicles of the same individual are taken in the cadaver, and compared with the total *shoulder-width* (not bi-acromial) PARSONS found, in 50 male bodies, the length of the right clavicle to average .382 of the shoulder-width, and that of the left, .387. In 49 female bodies the respective figures were .380 and .383, thus showing more definitely the greater length of the left clavicles in both sexes.

II. INDICES

1. *Caliber index* [2 : 1] $\frac{\text{middle circumference of shaft} \times 100}{\text{maximum length}}$

2. *Clavicle-humeral index* [1 : 1 of humerus]

$$\frac{\text{maximum length of clavicle} \times 100}{\text{maximum length of humerus}}$$

ARM AND HAND

Humerus

I. MEASUREMENTS

1. *Greatest maximum length* [AB, Fig. 31]; taken with the osteometric board.

2. *Breadth of the proximal epiphysis* [AC]; taken from head to greater tuberosity, so as to get the greatest measurement. Use the slide compass of the rod compass.

3. *Breadth of the distal epiphysis* [BE]; measured between the two condyles, to get the greatest measurement. On about the same plane as No. 2.

4. *Circumference of the diaphysis at the upper third;* this is preferred to that taken in the middle of the shaft, as it avoids the deltoid eminence.

5. *Least circumference of the diaphysis;* this is found at about the second third, distal to the deltoid eminence, and just proximal to the beginning of the supra-condyloid ridges. It is usually about a centimeter distal to the nutrient foramen.

6. *Proximo-distal (longitudinal) diameter of the head;* taken from a point in the edge of the articular surface of the bone across to the opposite side, taken in a plane parallel to the long axis of the bone. SC.

7. *Dorso-ventral (transverse) diameter of the head;* taken in the same way, but at right angles to the previous one, and at right angles to the long axis of the bone.

8. *Circumference of the head;* measured around the margin of the articular surface, with the tape.

II. INDICES

1. *Caliber index* [5 : 1] $\frac{\text{least circumference of diaphysis} \times 100}{\text{maximum length}}$

2. *Index of the head* [7 : 6] $\frac{\text{transverse diam. of head} \times 100}{\text{longitudinal diam. of head}}$

III. ANGLES

1. *Angle of torsion;* the angle formed by the line connecting the cener fo the head and the greater tuberosity, when projected upon the

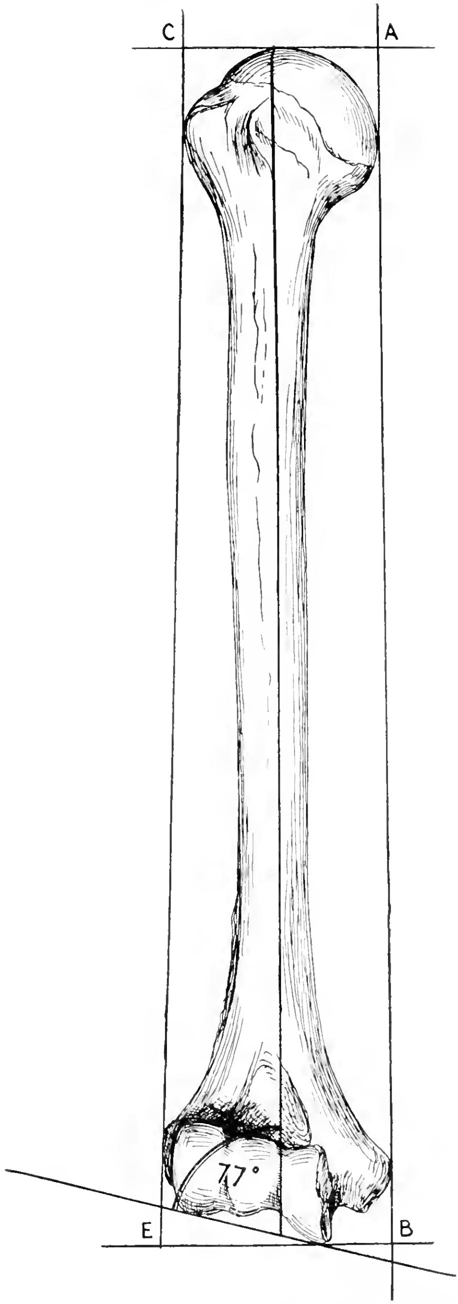

FIG. 31.—Right humerus, showing the cubital angle.

line connecting the two condyles; i.e., the axis of the head and the axis of the condyles (Fig. 32). This is taken by means of the parallelograph.

2. *Cubital angle;* the angle formed by the axis of the shaft with that of the trochlea. This is taken by standing the bone upon the table, the trochlear surface in contact with it. The angle to be measured is that of the bone with the table. This angle, taken in connection with that formed by the olecranon and shaft of the ulna, (joint axis angle,

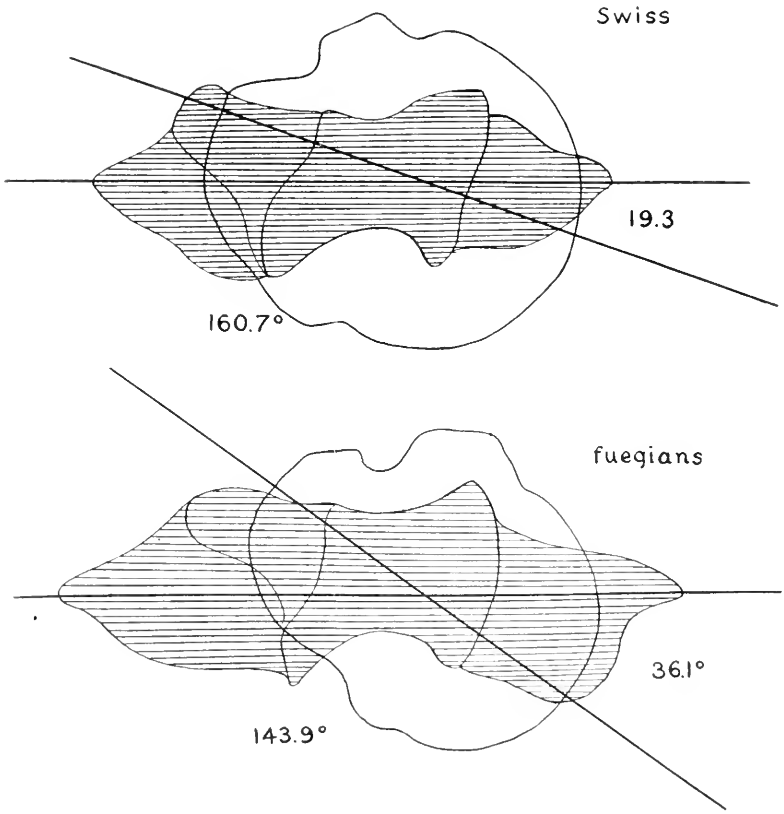

Fig. 32.—Contours of the two ends of a humerus superposed upon each other in bones from two different races, to show amount and angle of torsion. (*After Martin.*)

see below, under *Ulna*), determines the degree of obliquity of the fore arm upon the upper arm in life, the "elbow angle" which is usually so much more pronounced in females than in males as to constitute almost a secondary sex character.*

The anthropological study of the humerus is as yet too new either to estimate the relative value of the data given, or to formulate definite results from them. A few suggestions may be permitted, based upon the

* Martin found the average value of the cubital angle in Fuegian humeri to be 83°, and that of the Swiss, 77°. Other authors have established an average of 70° for the white race. For the discussion of the elbow angle, see below, under *Ulna*.

humerus of *Homo neandertalensis*, and other extinct forms, as well as from the study of this bone in other Primates, suggestions which show the tendencies i.e., the lines along which the human specialization is moving. Thus, contrary to expectation, the humerus in the modern type is distinctly longer than in the Neandertal species, that of the right humerus of the latter being but 312 mm. long, although the cranium was very large. It is, however, extremely robust, although, from the few fragments extant, the hand was rather small and delicate. The shape of the head of the humerus is peculiar, being broader than long, that is, measurement No. 7 exceeds that of No. 6, and the Index (No. 2) is more than 100, a condition that does not exist in modern man, so far as is known. The direction taken by the head, as shown by the angle of torsion, is more towards the back than in the European race, resembling that of Australians and other lower races. The value of the angle of torsion in various other mammals, and in several human races, is as follows:*

Carnivora	85.1°
Hylobates	68.0
Simia	59.75
Pan	52.0
Australians	45.5
Gorilla	39.0
Negroes, Fuegians, Polynesians	36.0
*Neandertal (right)	35.0
Chinese	33.13
Neolithic French	27.68
Ancient Parisians	24.6
Swiss	19.0
Modern French	16.0

Among the characters classed as variations two have especially attracted the attention of ethnologists; the perforation of the olecranal fossa, and the supra-condyloid notch. The first is the result of unusually deep coronoid and olecranal fossæ, opposite each other upon the two sides of the bone, immediately over the trochlea. This occurs in some 4–5% of Western Europeans, but is more common in African negroes (21.7 %), and in Polynesians (34.3 %), and is still more frequent in American Indians (36.2 %). It seems to have been more common still in prehistoric peoples.

The second character is clearly a remnant of the supra-condyloid foramen of lower mammals, and, when well-developed, as occasionally

* In taking the angle of torsion some authors use one of the two complementary angles, and some the other. It is thus often necessary to reduce all to a common form by subtracting from 180°. This was done in this table, which is taken from data given by Broca, Martin, and Duckworth.

in modern man, consists of a hook-like process upon the internal condylar ridge projecting distally, and converted into a complete foramen in the recent state by a ligament. It transmits the Median nerve, and frequently also the Brachial artery, or a branch arising from it, as in the case of the complete foramen of certain other mammals. In the humeri of the Spy and Neandertal skeletons there appears a groove (*Sulcus supracondyloideus*, Klaatsch), evidently the vestige of the foramen in a slightly different form.

Ulna

The treatment of this and the following bone (Radius) is based largely upon the excellent model set by the paper of Fischer,* which differs in its arrangement from the more usual one. Instead of listing first the measurements, then the indices, and then the angles, he treats of a side, aspect, or end with all its data together, a method which is here followed. The numbers thus follow consecutively, without placing angles, indices, etc., in separately numbered lists.

I. LENGTHS AND CALIBER

1. *Maximum length;* measured either upon the osteometric board, or by means of calipers. This measurement includes, naturally the extreme points of the olecranon and the styloid process, which, in the case of measurement by the calipers, become the points upon which the feet of the instrument rest, the termini of the maximum length line.

The longest ulna measured by Turner, that of a male Hindu, was 305 mm.; Fischer's longest, out of several hundred, was 296. In the Sikh, a very large race, Turner's maximum was 297, in the Malay 265, and in the Chinese 247. In negroes the maximum ulna was 301. The females of all these show considerably lower maximum figures, as would be expected.

2. *Physiological length;* measured with the calipers, the two measuring points, or termini, being (1) the deepest point in the longitudinal ridge running across the floor of the greater sigmoid notch, and (2) the deepest point of the distal surface of the "head," not taking the groove between it and the styloid process.

Although the maximum length line has long been used as the main, or the only, length measurement, there are many reasons for preferring the "physiological" or effective length; more in fact than in the radius, where it is also recommended. This length is that included between the articular surfaces, and is to be preferred, not only because it avoids the necessity of using the points of the olecranon and styloid processes, which are often incompletley preserved, but also because it corresponds to the effective working length of the forearm, as measured upon the volar side.

* Fischer, Eugen: Die Variationen an Radius und Ulna des Menschen. Zeitschr. für Morphol. und Anthropol. Bd. IX. 1906, pp. 147–247. 5 Pls., 16 text-figures, and 6 tables. (This paper is fundamental for the anthropological study of Ulna and Radius.)

The following averages of this measure are given by Fischer:

Prehistoric Teutons (Reihengräber)	239.7*
Negroes (6)	239.5
Africans in general (12)	234.6
Australians (6)	233.7
Melanesians (17)*	230.5
Germans (Baden) (25)	227.2
Ainu (60)†	212.5
Japanese (40)†	200.4

Compared with these figures the species *H. neandertalensis* shows nothing distinctive, but comes quite within the limits of recent man. The Neandertal ulna (right) measures 231 mm., physiological length, and those of Spy are estimated by Fischer at about the same figure (Spy I, Right; 233; Spy II, Left, 231). The orang, with its phenomenally long arm, shows a physiological length of 340.5. In the gorilla it is 303.21 in the chimpanzee 269, and in the gibbon, the smallest of the Simiidæ in body, it reaches 282.2, a larger actual measurement than in any normal man.

3. *Least circumference of the diaphysis;* located a little above the distal epiphysis, where the shaft, through the reduction of the muscular ridges and crests, becomes nearly cylindrical. Measured with the tape.

4. *Caliber index;* $(3 : 2) = \dfrac{\text{least circumference (3)} \times 100}{\text{physiological length (2)}}$

By this index is expressed the relative delicacy or robustness of the bone as a whole, the larger the number the stouter the bone. The following table expresses in figures facts that have been frequently stated from observation; among others that the ulna of primitive people is more slender than that of the culture races. The extreme slenderness of this bone in the gibbon and orang is also manifest.

Caliber Indices of the Ulna

Simian apes	
Gibbon (4)	6.0
Orang (8)	10.0
Gorilla (5)	13.4
Chimpanzee (2)	14.3
Primitive human races	
Australians (6)	12.7
Melanesians (13)	13.7
Negritoes (6)	14.6
Culture races	
South Germans, Baden (25)	16.8

* The prehistoric Teutons, measured by Lehmann-Nitsche, and the last two, measured by Koganei, may not correspond exactly in the mode of measurement with the rest, which were calculated by Fischer.

† In these the two sexes were used indiscriminately, in the others the bones were those of males alone as far as could be determined.

II. STUDY OF LATERAL PROJECTION; CURVATURE OF THE SHAFT

A convenient plane, to be used in projections and in general comparison, is one established by Fischer, and conveniently called the *sagittal*, or *dorso-volar*, although in the natural position of the forearm, with the palm upwards and the radius and ulna parallel, it is set somewhat obliquely and is not perpendicular to the "volar plane," used in the study of the radius.

This plane is determined by the curved ridge that runs longitudinally across the greater sigmoid notch, from the volar point of the olecranon to the projecting point in the lip of the coronoid process. The plane of this curve also passes approximately through the styloid process at the distal end, and the bone may thus be conveniently adjusted for projection by placing both the curved line and the styloid process at equal distances from the plane of the paper. Using this plane the bone may be inspected from the two opposite aspects, the one displaying the lesser sigmoid notch the other not. For the outline of the entire bone either aspect is, of course, equally serviceable, but as the features of the lesser notch are used in some of the measurements, the side that shows it is to be preferred.

5. *Curvature index.* A comparison of several bones, or of their projections, in the plane just defined, shows a striking difference in the shape of the bone as a whole, due mainly to a variation in the amount of curvature in the shaft. This may be measured upon a projection from the lesser sigmoid aspect by the method indicated in Figure 33. A median longitudinal line is first drawn through the proximal end of the bone to serve as an axis, and this crossed by a perpendicular tangent to the lower (distal) border of the articular surface of the lesser sigmoid notch. This locates the point a, where this cross line intersects the outer marginal line. A line is now dropped from the point a towards the distal end of the bone, tangent to the slight inward curve that is always found in the outline just above the distal epiphysis. The exact point of tangency is the point b, and the line ab is the chord of the outer outline, the curve to be measured. When this has been done the amount of curvature is ascertained by measuring the longest perpendicular to the chord that can be erected within the limits of the curve, and this length is expressed in terms of the entire chord by means of the following formula; $\frac{\text{longest perpendicular} \times 100}{\text{length of chord } AE}$. The result is the curvature index, the greater curve giving the larger number.

6 *and* 7. *Height of olecranal cap, and olecranal cap index.* A second measurement obtainable from this lateral projection is that of the height of the olecranal cap (No. 6), the amount of projection of the olecranon process above the upper lip of the greater sigmoid notch. The wide differences that are possible in this respect are seen at once by comparing any human ulna, in which the projection is slight, with the ulna of almost

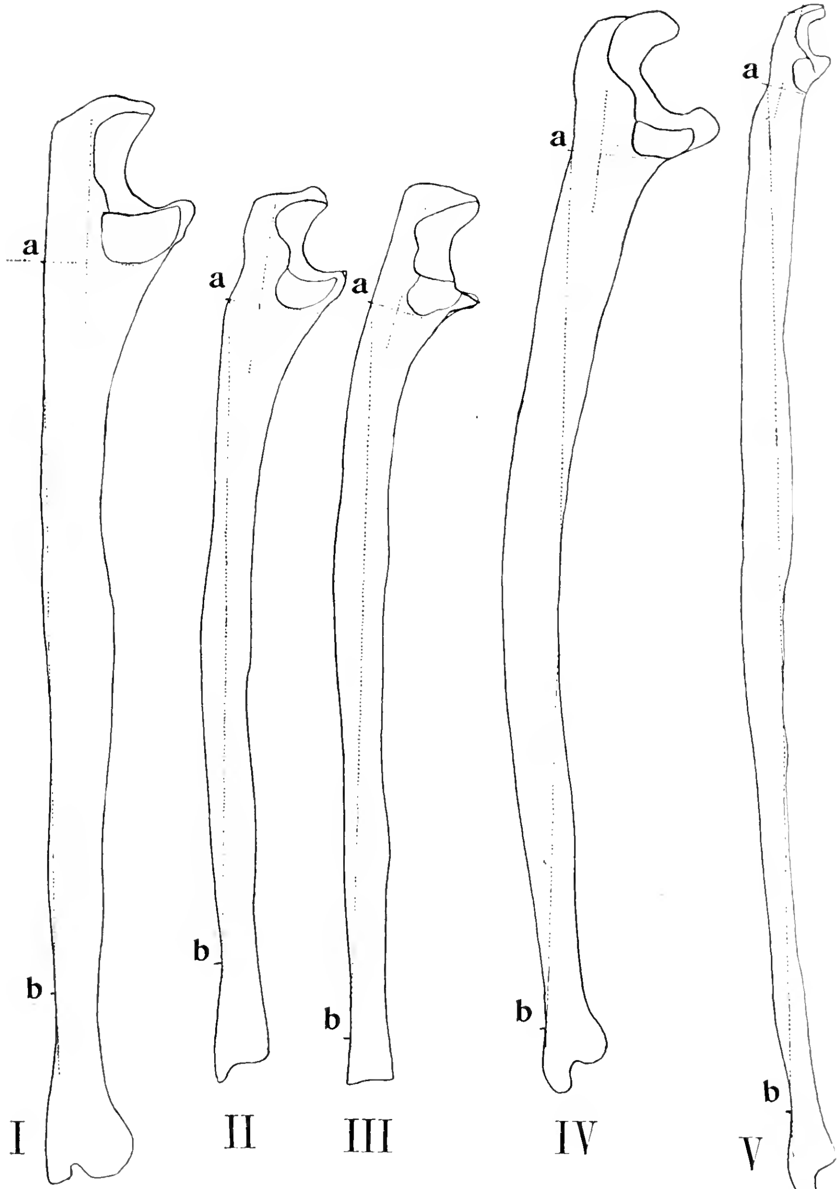

Fig. 33.—Outlines of five ulnas, human and anthropoid, showing varying degrees of shaft-curvature. Further explanation in the text. *After Fischer.*)

I. South German (Baden)
II. Australian
III. New Mecklenburg (female)
IV. Chimpanzee
V. Gibbon

any quadruped, such as a cat or a rabbit. In various human ulnæ there are considerable differences, the measurement of which may be made by first establishing upon the projection the longitudinal axis of the proximal end of the bone, and crossing this with a perpendicular, tangent to the upper lip of the greater sigmoid notch. The height of the olecranon above this is the measurement sought (n in Fig. 33).

The olecranal cap index (No. 7) may be obtained by comparing this measure with that of the physiological length of the entire bone; as follows:

7. *Olecranal cap index* (6 : 2) $= \dfrac{\text{height of olecranal cap (6)} \times 100}{\text{physiological length (2)}}$

In modern men this index varies individually between 0.6 and 3.7, the larger figures occurring in the more primitive human races, although with some notable exceptions. In *H. neandertalensis* the cap is high, but in the Simian apes it is low. On the other hand the lower monkeys in general have a much higher cap than is found in any human races, some of them approaching the quadrupeds in this particular. The table of olecranal cap indices follows:

H. sapiens:	
South Sea islanders (6)	1.2
Melanesians (13)	1.7
South Germans, Baden (25)	1.7
Australians (6)	1.8
Africans (8)	1.9
Negritoes (6)	2.0
Fuegians	2.5
H. neandertalensis:	
Neandertal	4.6
Spy II; right	4.0
Spy II; left	3.8
Simian apes:	
Gorilla (4)	0.8
Gibbon (4)	1.0
Orang (9)	1.1
Chimpanzee (2)	1.4
Lower apes (23), miscellaneous	6.4
Lemurs	8.3

8. *Olecrano-coronoid angle.* This character, also brought out by the lateral projection, is the position or tilt of the greater sigmoid notch, taken as a whole, as compared with the long axis of the bone. This can be readily expressed by the value of the angle formed between the chord *ab*, previously defined, and the prolongation of the line drawn across the points of the upper and lower lips of the notch. If, as is sometimes the case, the two lines are parallel, the angle is naturally O, and the notch faces straight outwards; when, however, the notch has an upward tilt, the two lines intersect above and form an angle which becomes greater the

more the opening of the notch is elevated (Fig. 33, I and II). Should this look downwards the intersection would be below and the angle would be given a minus value.

On an average, in modern races, this angle has a value of 15–20°; but an angle of 32° has been recorded. The value of this angle which, from the two points involved, is termed the *olecrano-coronoid*, is directly concerned in the question of the angle formed at the elbow during the extension of the arm, since a complete extension to 180° is more easily possible, other things being equal, when the olecrano-coronoid angle is large, that is, when the notch is directed upwards. This possibility of complete extension is, however, dependent upon other factors also, for example, the depth of the olecranon fossa, or a slight forward cant of the olecranon process as a whole; so that an unusually deep fossa, or perhaps a perforation of the bone (supra-trochlear foramen), may compensate for a moderately low position of the greater sigmoid notch, and still render a complete extension possible. When, however, the angle is very small, and the notch has little or no upward direction, a complete extension, even with these compensations, is quite impossible. This is the condition in *Homo neandertalensis* so far as known; the olecrano-coronoid angle is low, and the extension of the arm is incomplete, the bones, when articulated, forming an angle of 160–165° when fully extended, so that, in the flesh, allowing for the space taken up by the soft parts, the amount of extension must have been even less.

In the lower monkeys the olecrano-coronoid angle is very low, in some cases even negative (notch pointed downwards) and it would seem that here also a complete extension is impossible. Many human races, on the other hand, both high and low, such as the Central Europeans and the Australians, possess a high angle, and presumably have the power of complete extension. Definite statements on this point cannot be made from lack of sufficient data, and more detailed study, not only upon the bones but more especially upon the living, including all races and both sexes, are a pressing need.

III. STUDY OF THE VOLAR PROJECTION

This projection is that of the bone when rotated about its longitudinal axis exactly 90° from its former position, showing the curved longitudinal ridge that crosses the greater sigmoid notch as a straight line. As the former position was not strictly lateral, though called so for convenience, so this position is not quite volar, but in the normal position of an extended arm is set at nearly 45° to the "volar plane" of the radius, described in the next section. Like the aspect previously used, however, it best shows certain essential peculiarities and has the advantage of being consistent with it.

From this aspect the entire shaft is seen to possess a very slight S-curve, but it is difficult to measure, and thus far has yielded no important result. Of much greater significance is the angle expressing the relation of the plane of motion of the elbow joint to the longitudinal axis of the shaft, which can be ascertained with some accuracy from such a projection, the joint axis angle.

9. *Joint-axis angle.* To determine this first draw upon a given volar projection the line AE (Fig. 34), coincident with the curved longitudinal

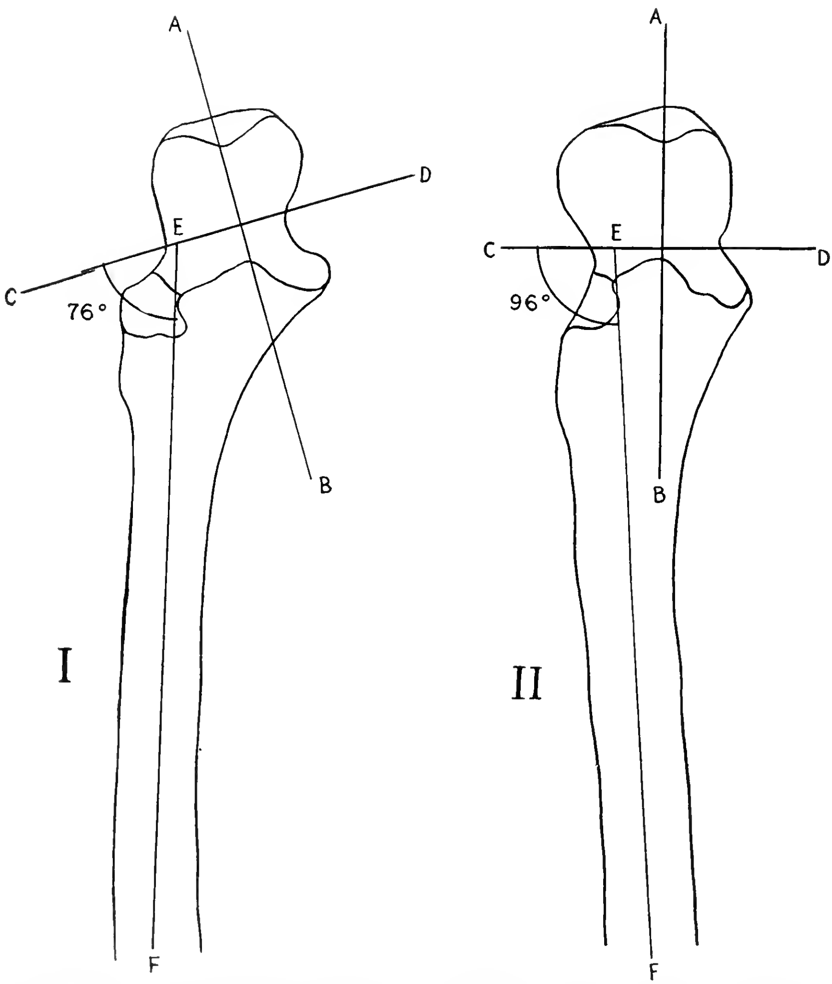

FIG. 34.—Ulna of I, White (So. German), and II, Negro, to compare the joint-axis angle in the two. (*After Fischer*).

ridge of the greater sigmoid notch, which is used in determining the lateral plane. This marks the plane along which the forearm moves in flexion and extension. Next draw a perpendicular across this at any convenient place with the limits of the notch, as CD, and this line, which is perpendicular to the plane of rotation, must necessarily be parallel to the axis of the joint. If, now, the axis of the shaft be drawn, EF, intersecting the line CD at E, the angle formed, CEF, is that between the joint axis and that of the ulna, or of the forearm, the *joint axis angle*.

10. *Lateral divergence angle.*—This angle, which is that made between ulna and humerus during extension, might equally well be placed under either bone, since it involves both to an equal degree. Under the more common name of the "Elbow angle" its more extreme case, in which the two parts, upper and lower arm are set obliquely to each other in the living, this angle has been frequently noted and extensively commented upon. The true relation of these two parts is naturally a matter of the bones concerned, and is due to the two angles, *cubital* (Humerus III, 2)

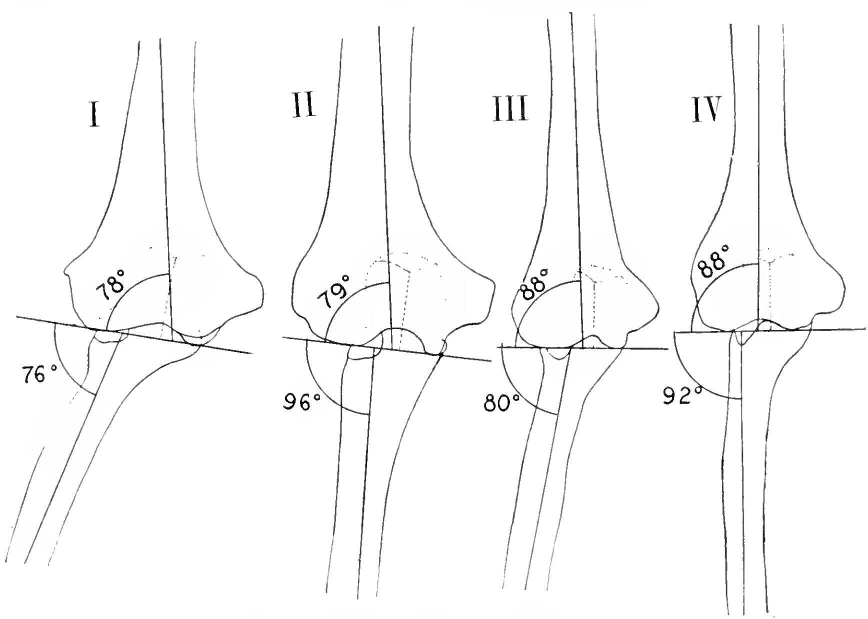

Fig. 35.—Lateral divergence angle of elbow joint. (*After Fisher.*)
I South German (Baden)
II Negro
III Australian
IV Australian

and joint-axis (Ulna, 9), which may vary quite independently of each other The four possibilities are presented in Fig. 35, taken from Fischer. In the first case both cubital and joint axis angle are considerably less than 90°, i.e., the axes are both obliquely set, the result being a pronounced divergence of the forearm from the line of the humerus; in II, where the cubital angle is oblique, and the joint axis nearly straight (the angle even more than 90°), and in II, where the reverse is true, and the cubital angle is straight (88°), there is a moderate amount of lateral divergence. In IV each angle is practically a right angle, one compensating exactly with the other, (88° and 92°), and the result is a perfectly straight arm. It is thus seen that the lateral divergence angle (elbow angle of some authors) is always the sum of the two angles, *cubital angle* of the humerus and *joint-axis angle* of the ulna. That of 1 equals 154°; of II, 175°; of III, 168°, and of IV, 180°.*

IV. PROPORTIONS OF THE OLECRANON

Certain of these, relative to the olecranal cap (Nos. 6 and 7) have already received treatment. There remain now the more usual dimensions of length, breadth, and thickness (or depth), with the customary indices to express the relations between them. These are here tabulated, although their value or significance have not yet been proven.

11. *Maximum breadth of olecranon;* measured with the sliding compass at right angles to the olecrano-coronoid ridge used to define the sagittal plane.

12. *Height of olecranon;* measured from the transverse line, groove, or roughness, which runs partly across the concavity of the notch from the outer side, separating the articular surfaces of olecranon and coronoid process, up to the highest point of the olecranon, i.e. the top of the olecranal cap.

13. *Thickness (or depth) of olecranon;* measured with the sliding compass from volar to dorsal aspects. This is taken across the lip above the notch.

14. *Thickness-breadth index of olecranon* (13 : 11)

$$= \frac{\text{thickness of olecranon} \times 100}{\text{breadth of olecranon}}$$

15. *Height-breadth index of olecranon* (12 : 11)

$$= \frac{\text{height of olecranon} \times 100}{\text{breadth of olecranon}}$$

These last two indices have yielded the following values:

	Thickness-breadth (14)	Height-breadth (15)
H. sapiens:		
Negroes (11)	92	83
Weddas (3)	96	85
South Germans, Baden (25)	98	80
Australians (6)	98	80
Melanesians (18)	104	88
Negritoes (6)	107	90
Fuegians (6)	107	85
H. primigenius:		
Neandertal	97	86
Spy I	92	83
Spy II	100	86

* For special studies of the elbow angle see NAGEL: Untersuchungen über den Armwinkel des Menschen. *Zeitschr. Morphol. u. Anthropol.*, Bd. 10, 1906–07, and MALL: On the angle of the elbow, *Amer. Journ. Anat.*, Vol. 4, 1905, pp. 391–404.

Simian apes:		
Gibbon (4)	88	75
Orang (11)	95	81
Gorilla (5)	101	77
Chimpanzee (2)	120	73
Lower apes	165	153.9
Lemurs	120	138

V. SHAPE OF THE SHAFT

Through the formation of longitudinal ridges the shaft of the ulna becomes more or less definitely a three sided prism, one edge of which, the one turned towards the radius, forms a sharp crest, often considerably developed. Aside from these there are many minor elevations and slight depressions, which have their meaning for the anatomist in relation to the attachment of muscles, but in which thus far no racial characters have been established, and it is more probable that the variations are mainly those of age, sex, and degree of muscular development.

Two methods have been devised, however, for determining the shape of the shaft at different levels, the one mechanical, the other mathematical. The first consists of surrounding the shaft at a given level with a band of wax, which, when removed, gives the exact form of the part enclosed. For this a mixture of wax and paraffin, 4 : 1, is warmed to the degree necessary to make it plastic, worked a little between the fingers, and then pressed around the region selected in the form of a band. The upper and lower margins of this band are then made straight by means of a knife, and the whole is then plunged into cold water to harden. When sufficiently hard the ring is cut across at two opposite points and the two halves are removed quickly from the bone and dropped upon a table or board without being handled. They are then placed together and fastened by means of a hot spatula applied to the outer surfaces. In this way may be obtained the outlines of any section, but the two points of greatest interest are (1) the point of greatest crest development, and (2) the cylindrical region above the distal epiphysis, where the ridges fail and the caliber is the minimum.

The second method is the more usual one of obtaining an index from two diameters taken at the same level and at right angles to each other. For this the point of greatest crest development is recommended, a point at about the upper third of the bone. Fischer uses for the two diameters the *dorso-volar*, from the ridge on the dorsal side to the flat plane on the ventral, and the *transverse*, exactly at right angles to the first. His index is formed by dividing the first by the second, or, in other words, by considering the transverse diameter = 100. Since in most ulnæ the shape of a cross-section at this place is triangular, there are obvious difficulties in establishing two diameters at right angles to each other, while a measurement that includes the crest would give, not the primary shape of the bone, but the degree of development of the crest itself, that is, the degree of muscularity of the indivdual, and not the fundamental shape of the shaft. Since, however, nothing better has as yet been devised, and since these measurements have been actually used by Fischer, they are added here.

16. *Dorso-ventral diameter of shaft at the upper third;* taken as suggested above.

17. *Transverse diameter of shaft at the upper third;* taken as suggested above, and exactly at right angles to the previous measurement.

18. *Caliber index* $\frac{\text{dorso-ventral diameter [16]} \times 100}{\text{transverse diameter [17]}}$

In this index the higher figures signify an approach to the cylindrical, a perfect cylinder being 100, while a lower index suggests a flattening of the shaft transversely. In Fischer's results the average index for South Germans is 76, for Fuegians, 86; and for Australians, 90. The ulnæ of Neandertal and La Naulette gave each an index of 100.

Radius

I. LENGTH MEASUREMENTS

1. *Greatest maximum length;* taken either with the osteometric board or with the calipers, using as termini (1) the highest point of the margin of the capitellum, and (2) the point of the styloid process. The maximum length of normal radii was found by Fischer to lie between 190 and 288 mm., the shortest average being found among the Negritoes and prehistoric pygmies from the Swiss lake-dwellings, and the longest among African negroes. Turner's longest radius, that of a negro, measured 287 mm., his longest Sikh radius was 267, longest Malay 250, and longest Chinese 227.

2. *Physiological length;* measured with the calipers from the deepest point in the bottom of the fovea capitelli (the articular surface which receives the capitellum of the humerus) to the deepest point in the semilunar facet at the distal end. Here, as elsewhere, the physiological length is the effective length for use, and is generally to be preferred, since it is that of the lengths of the parts in the living, thus enabling one to compare directly the figures in the living and in the bones. Thus here, the distance from the bottom of the external dimple or depression, so conspicuous an object in the dorso-lateral side of the living arm to the point of the styloid process, accurately located in the wrist, is the same as the physiological, rather than the anatomical, length of the bone. From the practical standpoint, in measuring a collection of bones, the physiological length is more generally applicable, since it does not depend upon the integrity of the styloid process, which is so often more or less deficient.

The greatest average physiological length of the radius thus far recorded is that of the prehistoric Teutons from the "Reihengräber," for which the average of 25 separate radii is 237.3 mm.* Next follows the negro races, with an average of 235 to 238. Among other races are the following averages; although they rest upon too few single cases to be final: Australians, 227.3; Melanesians, 226.4; Polynesians, 210.3; Japanese, 200; Negritoes, 194.7. The physiological length of the Neandertal right radius is 225.

The Simian apes, with their notably long forearm, naturally show longer absolute figures than does even the largest man. Thus, for the gorilla we have 302.4; for the chimpanzee, 266; for the orang-utan 334.3; and for the gibbon, in spite of its small size, 257.8.

Several of the older anthropometrists, notably Turner, used a comparison of the lengths of humerus and radius to form a *Radio-humeral index*, in which the length of the humerus was taken as the standard (= 100), and the (anatomical) length of the radius compared with it. This evidently grew out of the still earlier observation on the relative lengths of the forearm and upper arm, which formed the starting point of the anthropometry of the limbs, as given in the Introduction. This may be recorded here.

3. *Humero-radial index;* $\frac{\text{max. length of radius} \times 100}{\text{max. length of humerus}}$

II. SHAPE AND PROPORTIONS OF SHAFT

4. *Least circumference of the distal half.* Most usually that circumference of a long bone which is selected for comparison with the length in estimating its proportionate caliber is the least one that can be found, which, in the case of most bones, is a fairly definite point. In the radius, however, there are three small places. (1) The "neck," between capitellum and bicipital tuberosity, (2) a point a little below this latter, and (3) a point just beyond the middle of the shaft, towards its distal end. In some bones one of these, and in others another, may prove to be the least circumference, so that, in order to be uniform, one must be designated as the one to use. The best for many reasons, and in more than half the cases the actually smallest place, is the last named, which may be definitely designated as the point to be measured. As in all circumferences the measure is taken by means of the tape.

5. *Caliber index* (4 :2) = $\frac{\text{least circumference (4)} \times 100}{\text{physiological length (2)}}$

This index expresses the degree of slenderness of the bone as a whole, the less the figure the more slender the bone. The following table shows that in general the radius is especially slender in the lower Primates, stouter in the Simian apes, and in the lower human races, and in the culture races the stoutest of all. The orang and gibbon, however, with

* LEHMANN-NITSCHE: Untersuchungen über die langen Knochen der südbayer. Reihengräberbevölkerung. Beitr. zur Anthropol. und Urgeschichte Bayerns. Bd. 9, München, 1895. This is also excellent for the other long bones of the skeleton.

their extremely long and attenuated forearms, are an exception to the general law, and belong in this respect with the lemurs.

Caliber indices of radius.

Gibbon (4)	8.1
Orang (10)	12.8
Lemur (5)	13.3
Melanesians (18)	15.7
Lower monkeys (20)	16.2
Burmese (8)	16.3
Negritoes (6)	17.0
Gorilla (5)	17.1
Germans, Baden (25)	18.1
Japanese (3)	20.2

The radius of *H. neandertalensis* contrary to expectation, is less slender than in the lower races of the recent species, the index being about like that of the culture races.

For the two following data, and for some others, one or more definite planes must be determined in which the bone may be placed and from which it may be viewed. The most obvious of these is the *volar plane*, or approximately that of the two forearm bones when the arm is stretched out in a supine position, with the palm up, a position which brings the radius and ulna parallel to each other. This plane is determined by a *line* and a *point*. The line, which is the maximum length line of the distal articular surface, extends from the apex of the styloid process to the middle of the concave edge of the incisura for the reception of the ulna. The point, which is placed at the opposite end of the bone, is the center of the depression in the capitellum, the fovea capitelli, the point used in the determination of the physiological length.

To place a given radius so that its volar plane lies parallel to the surface of the drawing table, that is, in a position for drawing a volar projection, the line and point must be placed at the same distance above the table surface. The *dorso-ventral*, or *sagittal plane*, lies at exact right angles to this, and is obtained by first placing the bone in the volar plane and then rotating it about its longitudinal axis 90°. With these planes determined the two following measurements may be easily taken, either upon the bone itself, or upon a dioptograph outline.

6. *Transverse diameter of the Shaft.*—This should be taken at the point of the greatest development of the crest, a point indicated not only to the eye, but to the finger, being designated by a certain roughness of edge that corresponds anatomically to the insertion of a specially strong band of fibers forming a part of the interosseous ligament. The diameter lies in the volar plane.

7. *Sagittal diameter of the Shaft.*—This must be at the same level as the last, but in the sagittal plane, 90° from the last.

8. *Diaphyseal index* (7 : 6) $= \frac{\text{sagittal diameter (7)} \times 100}{\text{transverse diameter (6)}}$

This index is of rather questionable value, and gives little more than an indication of the degree of development of the interosseous crest, which can be noted almost as well by the eye. Where the crest is large the transverse diameter is considerably in excess of the sagittal, and the shape of the cross section at this place is somewhat triangular; where there is little or no crest, on the other hand, the diameters are nearly equal, and the cross section approximates a circle. In the first case the index is a low number (72–75); in the second it is higher, reaching in the Simian apes to above 80. Here also the figures for *Homo neandertalensis* are unexpected, and resemble those of recent men, evidently because of their high crests. As in the case of the ulna the study of cross section outlines, both at this place and at others, is of more value than this index. Such outlines are prepared by the method described by the use of girdles of wax (cf. ulna). If these bands be filled with plaster of Paris little disc-shaped pieces are obtained, which represent actual cross sections which are very convenient for comparison.

III. STUDY OF THE VOLAR PROJECTION

Several striking differences in general form are brought out by comparing several radii placed in the volar plane, or, what is the same thing, by comparing a series of volar projections (Fig. 36). The two most important points are the *collo-diaphyseal angle* and the *amount of curvature of the shaft* as a whole.

9. *Collo-diaphyseal angle.*—This is obtained in the projection by marking upon it the axes of the two parts in question; (1) of the head and neck, by a line connecting the center of the head, through the middle of the shaft as far as the tuberosity, and (2) of the next ensuing portion of the shaft. The angle thus formed may then be measured by means of the transparent protractor. If one is dealing with an actual bone instead of a projection, the bone must first be properly oriented, and then the two axes marked by means of fine knitting-needles, attached to the bone surface by wax or plastilena. The angle is then read as before.

Where there is no bend between the two parts considered, the head-neck axis, and that of the ensuing portion form a continuous straight line, and the angle = 180° (Fig. 36, I). This has been found in South Germans, although the average is 171.6°. A slight bending reduces the angle, which thus becomes less the greater the amount of bending exhibited. The average angle for Australians is 165.4, and of Fuegians, 160.4, showing a progressively greater amount of bending in these races as compared with Europeans. The Neandertal race, at 166°, shows an amount of bending comparable with that of the lower modern peoples, and the bending in the higher apes varies from 165° to 159°.

10. *Curvature index.*—The amount of curvature of the whole shaft may be expressed, in a way, similar to that used for the ulna, by fixing a

definite tangent line along the convex side of the curve, and constructing upon it the longest perpendicular. To fix the line, which is tangent

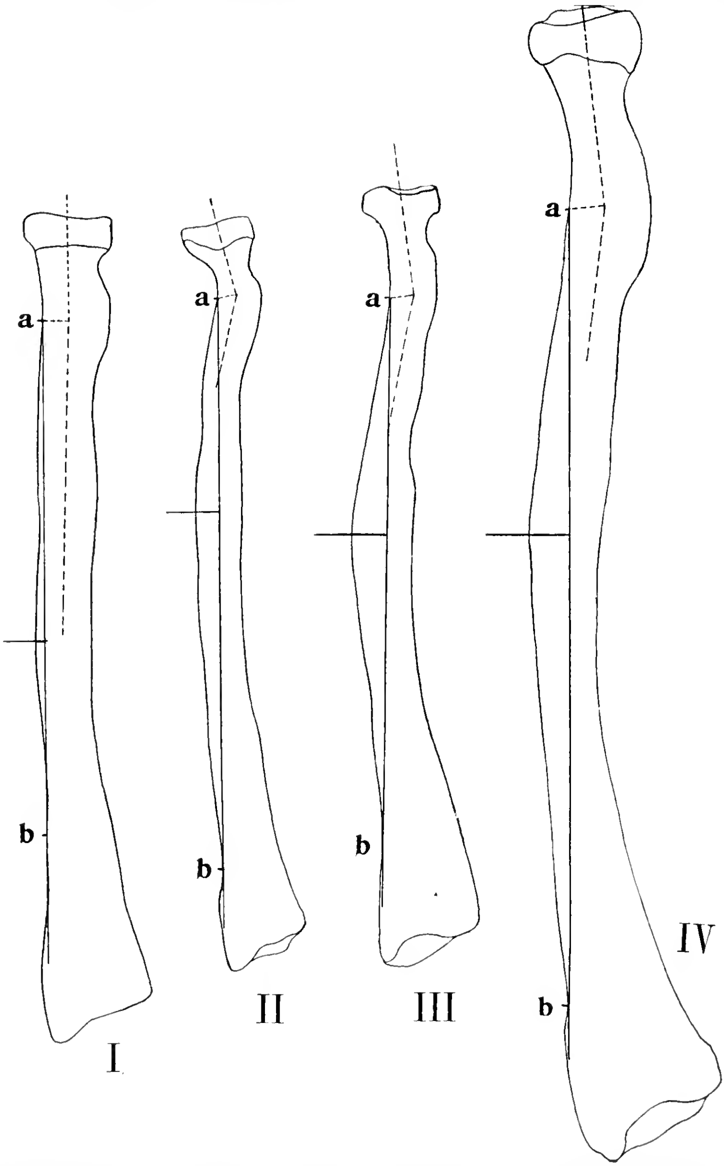

Fig. 36.—Outline of four right radii, human, prehistoric, and anthropoid, showing the collo-diaphyseal angle. Further explanation in text. (*After Fischer.*)
I. South German (Baden).
II. New Mecklenburg.
III. Neandertal.
IV. Gorilla.

to the inner curves, and not the outer ones, a perpendicular to the first of the axes used in the previous measure, that of the head and neck, which marks the point a, on the margin (Fig. 36). The point b is the deepest point of reëntrance of the distal curve seen on this outline, as shown also in Fig. 36. Now, connect by a line points a and b and we have the tangent sought. Finally, upon this as a base erect the longest possible perpendicular to the outer line of the margin, and the proportion of this to the entire tangent ab will indicate the amount of curvature; thus $\frac{\text{height of greatest perpen.} \times 100}{\text{length of tangent chord } ab}$

This index is always a small one, varying from 2 in modern culture races to over 6 in the strongly curved radii of the Neandertal species. Where the curve is large, it indicates a broad interosseous space, which in turn suggests a large surface for the origin of the finger flexors, and an ability to cling very tenaciously to such an object as a tree limb. In this connection the large amount of curve in the Neandertals is significant.

Table of Shaft Curvature Indices, Averages

Higher apes	
Gorilla	5.7
Orang-utan	5.1
Chimpanzee	4.3
Gibbon	3.6
Homo neandertalensis	
Neandertal specimen	5.2
Spy I	6.5 (approx.)
Spy II	5.2 (approx.)
Homo sapiens	
South Germans	3.2
Melanesians	3.0
Burmese	2.7
Fuegians	2.5

IV. STUDY OF THE SAGITTAL PROJECTION

In turning the bone around to a position 90° from the volar plane, it comes into the sagittal plane. Here but one important character has thus far been observed, and that is, a second collo-diaphysial angle, which marks the amount of backward projection of the proximal end of the bone. This can be measured by the same methods as are used for the collo-diaphysial angle of the volar plane (No. 9), and has been found to average 172.5° in the people of Oceanica and 175.0° among the South Germans, in both cases a greater bend than in the volar diaphysial angle. This angle may prove to be important, but thus far it has not been used very much, and need not be listed.

V. THE TORSION OF THE SHAFT

If in number of radii the maximum length line of the distal articular surface be plainly marked, that is, the line used above in determining the volar plane, and the bones be then placed in a parallel row upon a table, with the bicipital tuberosity looking straight upwards, there will be seen considerable difference in the angle which this distal line makes with the plane of the table. In other words the angle made between this line and one at the proximal end driven straight down through the tuberosity is subject to much variation. This angle is called,

11. *Angle of torsion.*—It is measured by the parallelograph, which places on a piece of paper placed on the table a projection of the two lines involved, in the case of a bone held in a clamp and placed perpendicularly over the table. The angle is then determined by the transparent protractor.

Viewed in another way this measurement defines precisely the direction towards which the tuberosity points when the bone is placed in the volar plane. If in this position the tuberosity points directly upwards, its axis is at right angles to that of the distal articular surface line and the angle is 90°; if it point laterally, along the crest, its axis lies in the volar plane and the angle is 0°. This is about the condition in the large apes, and in the Neandertal species of man; indeed, occasionally in an ape (apparently always in the chimpanzee) the tuberosity axis passes the 0 line, that is, the volar plane, and actually faces a little backwards, making a minus angle. In the white race in general the angle is somewhere around 45°, and consequently looks obliquely forwards and inwards.

The following results of the study of this angle have been found by Fischer, who, however, uses the complement of the angle as described here, considering the position in which the tuberosity looks directly upwards as 0°, and that in which it lies in the volar plane as 90°. The table here, in order to agree with the textual explanation has been translated into the complements of Fischer's table.

TABLE SHOWING THE ANGLE OF TORSION

Simian apes	
Chimpanzee	3.5°
Gibbon	+0.5°
Gorilla	2.0
Orang-utan	5.8
Homo neandertalensis	
Neandertal specimen	2.0
Spy	9.0
Homo sapiens	
Hawaiians	23.0
Melanesians	24.7
Australians	26.3
Negroes	26.7
Fuegians	29.5
Burmese	31.6
Veddah	37.0
Negritoes	37.5
South Germans (Baden)	39.8
Lake-dweller pygmies (prehist)	49.2

Although in averages this character is sufficiently striking, yet there are very large individual differences. Fischer found, for instance, among six negro radii, extremes of 39 and 85°; and among twenty-five South Germans, those of 22 and 67°.

The Bones of the Hand

Of all parts of the human skeleton it is safe to say that the bones of the hand and foot are anthropometrically the least known, and that in spite of the fact that, as always among highly differentiated parts, it is to be expected that they would reveal important racial differences*. The reason for this lack is mainly to be found in the paucity of available material. Few anthropological collections contain complete sets of hand and foot bones. In the case of those obtained from dealers, either attached to skeletons, or obtained separately, there is no guarantee that all the bones of a set came from a single individual and are not "composites," put together from several sources, and hence valueless for anthropometry. Again, it is very seldom that in an excavated skeleton these small and fragile parts are found complete, or even approximately so, since the lightness and smallness of the most of these parts allow them to become scattered by the action of worms and insects, and by various other sources.

To remedy this great defect, and supply material for his own university, Dr. Wilhelm Pfitzner of the University of Strassburg macerated and prepared with his own hands a collection of nearly 2000 human hands and about the same number of feet, not daring to entrust to a trade preparator any portion of the work.† Thus this place, and this alone thus far, possesses a priceless collection of just the material needed for anthropometric examination of hand and foot skeletons, but even here the collection is derived wholly from the local Alsatian population, representing but a small part of Europe. Adachi, in Tokyo, has been able to collect valuable data concerning the Japanese, but by the study of far fewer individuals, and when Uhlbach recently studied anthropometrically the hands and feet of Hottentots, he was obliged to content himself with these parts from only six individuals, and had it not been for the painstaking excavations by his friend and teacher, Fischer, he could not have gotten even these.

Granting, however, that material is not lacking, a distinct problem presents itself in the fact of the multiplicity of single bones which together make up the unit whose proportions are especially to be studied. That is,

* Geo. S. Huntington, in a lecture delivered before the Galton Society, New York, Dec., 1918 (unpublished).

† Pfitzner, W.: Beiträge zur Kenntniss des menschlichen Extremitätenskelets. VIII. Die morphologischen Elements des menschl. Handskelets. *Zeitschr. f. Morphol. und Anthropol.*, Bd. II. 1900, pp. 77–157 and 365–678. There are other important papers upon the subject by this author, but this, the last of the series, has an excellent bibliography, and will serve to direct the reader to the subject in general.

except in the bones of carpus and tarsus, whose proportions, taken a bone at a time, are frequently found significant, the points of comparison are found in the dimensions of the palm as a whole, or the relative lengths of entire fingers, while little or nothing is to be expected from single bones. It is thus frequently necessary to use as data the total lengths and breadths of several bones together, in which work the exact identity of every phalanx is of the utmost importance.

For convenience of treatment the proportions of the hand as a whole, or without the carpus, and those of the separate carpals, are here treated separately, and in the order mentioned.

I. THE PROPORTIONS OF THE HAND (WITHOUT THE CARPUS)

This part consists of the 14 phalanges, together with the 5 metacarpals, 19 bones in all; their measurements, used either separately or in combination, consist of *lengths*, *breadths*, and *depths* (dorso-ventrally).

1. *Lengths.* There are two possible lengths of phalanx or a metacarpal; the *anatomical* or maximum length, and the *physiological*. The first includes all processes or ridges which may be found prolonging the articulations, and this length is taken either by the anthropometric board or by a slide compass with flat points.

The ordinary type of osteometric board is too large and heavy for all except the metacarpals or the basal phalanges, and for this sort of work a much smaller size should be constructed, delicate enough to measure accurately, at least to half-millimeters, a bone the size of a terminal phalanx.

The physiological length, or that length which is actually effective when the articulations are closed together as in life, is that found by measuring the length from the center of the depression of the articular surface at one end by that of the other. This seems, and probably is, the best one to use in calculations requiring the length of an entire finger, since, when put together in the natural manner, the length contributed by each piece would be its physiological, and not its maximum length.

2. *Breadths.* The usual practice in ascertaining the breadth of a given phalanx, with its difference in caliber, and hence of breadth, at various points, is to measure the exact breadth at three places, across the two epiphyses and the middle, and average all three by adding them together and dividing by 3.

3. *Depths* (Heights). This measure, taken dorso-ventrally through a phalanx, at right angles to the previous one, is usually taken in the same way as the last, by the average of three measures, taken in the same places as the last.

4. *Calibers.* The caliber of the separate phalanges is a set of measures that will become important in the future without much doubt, but has not been employed thus far, probably owing to the technical difficulty of making a sufficiently accurate measurement to be of much discriminative

value. To use this measure more delicate methods than any we have at present must be devised.

As an example of data which may be derived in this way we present here the average lengths of the separate components of the middle finger (digit III) in Europeans, Japanese, and Hottentots, after the measurements of Pfitzner, Adachi, and Uhlbach respectively.*

Measurements of Digit III (Physiological Lengths)

bone	Europeans		Japanese		Hottentots
	male	female	male	female	
metacarpal	62.8	59.8	59.3	56.0	54.1
basal phalanx	43.4	41.2	42.3	40.4	35.8
middle phalanx	28.5	27.1	26.7	24.9	23.5
terminal phalanx	18.6	16.7	17.8	16.9	14.5
free finger	90.5	84.9	86.8	82.2	83.8
total digit (+metacarp.)	143.9	144.7	146.1	138.2	137.9

The following indices may be suggested, the most of which have already been employed by some of the above authors.

1. *Hand index.* This indicates the shape of the entire hand, whether long and narrow or short and broad; it is found by comparing the total length of digit III (metacarp. + ph1 + 2 + 3) with the physiological breadth of the four finger metacarpals, taken across their bases, thus:

$$\frac{\text{physiological basal breadth, metacarp. II} - \text{IV} \times 100}{\text{physiol. length, entire digit III}}$$

2. *Palmar index.* Like the previous one, save that the length of the palm is compared with its breadth, thus:

$$\frac{\text{physiological basal breadth, metacarp. II} - \text{IV} \times 100}{\text{physiol. length, metacarp. III}}$$

3. *Digital index.* Intended to compare the length of the palm with that of the free fingers, taking for the comparison the third digit, which is the longest, thus:

$$\frac{\text{physiological length, metacarp. III} \times 100}{\text{physiol. length, phal. } 1 + 2 + 3 \text{ of digit III}}$$

* Adachi, B. and Y. (Mme Adachi): Die Handknochen der Japaner. *Mitt. med. Fakultät Univ. Tokyo.* Bd. 6, pp. 349+.

Adachi, B.: Die Fussknochen der Japaner. *Mitt. med. Fakultät Univ. Tokyo.* Bd. 6, pp. 307+.

Pfitzner, W.: Maassverhältnisse des Handskelet. *Morph. Arb.*, 1892. Bd. 1, pp. 1+.

Uhlbach, R.: Messungen an Hand- und Fussskeleten von Hottentotten. *Zeitschr. Morphol. und Anthropol.*, 1914. Bd. 16, pp. 449–464.

4. *Thumb index* (*a*). The relative length of the thumb is obtained by comparing its total physiological length (metacarp. + basal ph. + terminal ph) with that of digit III, thus:

$$\frac{\text{physiol. length of thumb} \times 100}{\text{physiol. length of digit III}}$$

5. *Thumb index* (*b*). The relative length of the thumb, as indicated by its metacarpal, may be tested by comparing this latter bone with the metacarpal of digit III, thus:

$$\frac{\text{physiol. length of metacarpal I} \times 100}{\text{physiol. length of metacarpal III}}$$

6. *Breadth index* (separate phalanges). In this the breadth of a single bone, taken in three places and averages, is compared with the physiol length.

$$\frac{\text{average breadth} \times 100}{\text{physiol. length}}$$

7. *Depth index* (separate phalanges). As used by Uhlbach this index compares the average depth (height) with the average breadth.

$$\frac{\text{average depth (dorsal-ventral)} \times 100}{\text{average breadth}}$$

This might also be compared with the length, as in the previous index.

In carrying this investigation further, as is bound to be done soon, both here and in the case of the foot, one sees that the number of possible indices, taken with all the possibilities of comparing sums of separate bones, is practically endless, and the investigator should avoid an aimless multiplication of such possible data, using new indices only for some definite purpose, usually to put into mathematical form some difference of proportion already detected by the eye, or suspected as the result of measurement. The study and comparison with the hands and feet of the larger apes should here, as elsewhere, suggest certain lines of difference where racial criteria are to be looked for.

II. ANTHROPOMETRY OF THE CARPUS

This is the most neglected region anthropometrically of the entire skeleton, as thus far no definite measurements of single bones have ever been established, or definite indices used. Causes for this may be found in the small size of the bones, in the rarity of properly determined sets of carpal bones, and also in the fact that, although small, these bones are complex in form and in their mutual actions, and thus require an unusual amount of data to be of use.

It is likely that important characters may be found in the actions and habitual positions of these parts, or of the wrist as a whole, the exposition of which will involve more than single bones, mainly the proportions of adjacent articular facets and the mechanics of the possible motions between them. Again it will perhaps be sometime shown that characteristics of these sorts which seem to be racial may be in reality industrial or habitudinal, and have become the definite characteristics of a given race because of definite peculiarities in their racial culture. To illustrate this we have the claim of the two Adachis that the wrists and hands of the Japanese race are much more supple, and have a greater mobility that these parts in Europeans, and that this may be due to the harder forms of toil indulged in by the latter; not that they work harder, but that they are concerned with larger and heavier objects, such as larger tools, larger structures involving larger parts, and so on.

In the case of the tarsus the importance of the various foot motions, especially those of the ankle, involved, not only in walking and climbing, but in sitting and squatting, have already called especial attention to such bones as the calcaneus and the talus, and these parts have received much special attention anthropometrically, and from these one may get excellent models and many suggestions concerning the prosecution of further study of the carpus (cf. below). As much of value has been suggested in other regions by the comparison with the same parts in the large apes, it may be suggested that here would be an unusual opportunity for suggestive comparison by observation of the use of the hands and wrists in these animals, and a constant comparison with the use in man.

V. THE PELVIC SKELETON, INCLUDING HIP-GIRDLE AND SACRUM

Pelvic Girdle

Next to the skull the pelvic girdle, including the sacrum and the ossa coxæ (innominata) is of the most general interest, and the two have many attributes in common. Like the skull, the pelvic girdle is complex, formed by several separate elements, showing in the adult several degrees of fusion, but never with more than a limited amount of independent motion; both skull and pelvic girdle, too, are in many places quite superficial, and allow numerous measurements to be made with equal facility upon the bones of the living, with either no difference in the result, (*e.g.*, spinal breadth) or with only the slight difference caused by the thickness of the integument (*e.g.*, cristal breadth).

In another way the pelvic girdle is, in its treatment, like the skull, and that is in its need for orientation, and in its presentation of three dimensions, length [depth], breadth, and height. As in the skull there is a definite plane of orientation, the aim of which is to place the part in a natural position corresponding to that in the living. In the pelvic girdle, unlike the skull, the plane of orientation is vertical rather than horizontal, and the orientation is effected by placing the girdle, with its three parts (two ossa coxæ and sacrum) fastened together, in such a position that the two anterior ventral iliac spines, and the ventral surface of the pubic arch are in contact with a board placed vertically. From its three contact points it is called the *spino-symphysial plane*, and because it is defined by three points instead of four it is mathematically more precise than is the use of the FH with the skull, which depends upon four.

When oriented along the spino-symphysial plane the girdle possesses a maximum height, breadth (laterally), and depth (dorso-ventrally), approximately at right angles to one another, the first three measurements given below. Oriented in this way there are the usual number of normæ, as in the skull, which might come into use in making careful drawings or photographs for comparison, these have had little use thus far.

The anthropological study of the pelvic girdle is one of the oldest subdivisions of the subject, mainly, perhaps, on account of the early necessity of making measurements of this region in the female on the part of the obstetricians and gynæcologists. These men had thus assembled many data when the modern science came into existence, and all or nearly all of them found at once a place in the rubric of suggested measurements. Thus, in Turner's Report of the bones collected by H. M. S. Challenger (1886), the pelvic girdle, aside from the skull, to which an entrie monograph was devoted, has the first and most prominent place. No less that 35 separate data were presented, mostly measurements, with a few indices, and angles, and in this paper the Pelvic brim index (Turner's No. 15), originating from Zaaijer in 1866, was made much use of.*

I. MEASUREMENTS

(*a*) *Outside measurement of the pelvic girdle as a whole.*

1. *Maximum pelvic height;* the greatest distance between the upper edge of the iliac crest and the lowest point of the sciatic tuber (ischiadic tuberosity) of the same side. As the two terminal points are on the same bone, this measurement becomes also the maximum length line of a single os coxæ (innominate bone), and as such is employed in calculating certain indices, like the Innominate (3), and the Ischiadic (6).

2. *Maximum pelvic breadth* (*cristal breadth*)*;* the greatest distance between the two iliac crests, taken along the outer lips. This and other large pelvic and thoracic measures are taken with the *pelvimeter* (Pm), a large pair of calipers, with a reach of 600 mm.

3. *Maximum pelvic depth* (*dorso-ventral,* or *sagittal*). From the most dorsally projecting point of the sacrum, in the median line, to the

* An excellent paper to serve as a laboratory manual for the measurement of the pelvis is that of Koganei and Osawa, Das Becken, der Aino und der Japaner, Tokio, 1900, in which the authors have made an exhaustive study of the pelvis both in the skeleton and in the living subject, employing a large number of subjects in all cases. Earlier papers of importance, dealing with the racial differences, are Turner's Challenger report, referred to above, and Hennig, Das Rassenbecken, in Archiv f. Anthropol., 1885.

most ventrally projecting point on the ventral surface of the pubic symphysis. Pm.

4. *Conjugata externa* (*lumbo-pubic depth*); this corresponds to the like-named measurement on the living, and is taken between the same two points, the point of the dorsal spine of the fifth lumbar vertebra, and the most ventral point of the pubic symphysis. This measurement is naturally possible only in cases in which the fifth lumbar vertebra belonging to the same pelvis is present. It is carefully adjusted in its proper place where it is held by plastilena, and the measurement is then taken as directed. This measurement in the living exceeds that of the skeleton in the thickness of the two layers of integument and in the subcutaneous fat.

5. *Intertuberal breadth;* from the center of the lower surface of one sciatic tuber to that of the other. This should be the same value in living or skeleton. RC. We may also make use of either:

5*a*. *Outer intertuberal breadth;* measured from the most lateral points on the lower surface of the tubers, or

5*b*. *Inner intertuberal breadth;* measured from the most medial points on the lower surface of the tubers. In all cases it should be stated which measurement is used.

6. *Spinal breadth;* the distance between the anterior ventral (anterior superior) spines of the ilia, taken from their outer lips. The same value as in the living. RC.

7. *Acetabular breadth;* across the pelvic girdle from the center of the bottom of one acetabulum to that of the other. Pm.

(*b*) *Measurement of the pelvic basin.*

8. *Upper sagittal diameter* (*conjugata vera*); from the mid-ventral point of the anterior lip of the first sacral vertebra (promontorium sacri), across the basin to the upper end of the inner surface of the pubic symphysis, but not to the inward projecting process a little lower down.

9. *Lower sagittal diameter* (*conjugata diagonalis*); from the middle point of the promontorium sacri to the apex of the pubic angle, inner surface.

10. *Upper transverse diameter;* the greatest transverse diameter of the pelvic brim (ilio-pectineal line), at right angles to 8.

11. *Lower transverse diameter;* measured between the apices of the spines of the ischia. Only possible when the spines are intact.

12. *Oblique diameter of the pelvic brim;* upon the ilio-pectineal line from the ilio-sacral suture of one side to the region of the ilio-pectineal crest of the other side. This latter point corresponds closely to the original ilio-pubic suture, and lies above the lateral side of the obturator foramen. There are naturally two of these oblique measures, the dextro-sinistral and the sinistro-dextral; both should be measured, as pelves are frequently asymmetrical.

13. *Depth of the pelvic basin;* from the ilio-pectineal line in the region of the ilio-pectineal crest, to the lowest point of the sciatic tuber of the same side. This line measures the antero-posterior* depth of the lower pelvis, and runs along the lateral boundary of the obturator foramen.

(c) *Measurements of a single os coxæ.*

14. *Maximum length of the os coxæ;* this is the same as the *maximum pelvic height,* used in connection with the entire pelvis [cf. No. 1 above]. The termini are the upper edge of the iliac crest and the lower surface of the sciatic tuber, where the greatest length is sought. Cr.

15. *Maximum breadth of the os coxa;* the distance from the anterior dorsal (posterior superior) iliac spine to the anterior (upper) end of the pubic symphysis, that is, the anterior medial apex of the pubic bone. Cr.

16. *Length (height) of the ilium;* from the center of the acetabulum to the highest point of the iliac crest. SC or Cr.

17. *Breadth of the ilium*; across from the anterior ventral (anterior superior) to the anterior dorsal (posterior superior) spine of the ilium. Cr or RC.

18. *Length of the os pubis;* from the center of the acetabulum to the medial edge of the pubic symphysis, the maximum measure. SC.

19. *Length of the ischium;* from the center of the acetabulum to the lowest point on the surface of the sciatic tuber, the maximum measure. SC.

20. *Length of pubic symphysis;* this is the length of the roughened contact area between the two bones, measured along the medial border. SC.

21. *Vertical diameter of the acetabulum;* from the middle of the notch between the ends of the articular surfaces, measured upon the lateral edge of the obturator foramen to the opposite edge of the acetabulum where the diameter is the greatest. SC.

22. *Transverse diameter of the acetabulum;* the diameter taken at right angles to the preceding. SC.

23. *Vertical diameter of the obturator foramen;* the maximum antero-posterior diameter, taken approximately parallel to the lateral edge. SC.

24. *Transverse diameter of the obturator foramen;* the diameter taken at right angles to the above. SC.

* Note that here and elsewhere the nomenclature used is the morphological one, as related to any mammal, irrespective of his posture, whether bipedal or quadrupedal. Thus the terms *anterior* and *posterior* are equivalent to the older *superior* and *inferior* while the older terms *anterior* and *posterior* are replaced by ventral and dorsal respectively. Thus the common phrase "anterior superior spine of the crest of the ilium" is here the *anterior ventral spine;* the "posterior superior" is the *anterior dorsal;* the "anterior inferior" is the *posterior ventral* and so on. Also, in accordance with the BNA, *os innominatum* becomes *os coxæ,* and the *tuberosity of the ilium* the *sciatic tuber.*

II. INDICES

1. *Breadth-height index* (1 : 2) $\frac{\text{max. pelvic height} \times 100}{\text{cristal breadth}}$

2. *Breadth-depth index* (3 : 2) $\frac{\text{max. pelvic depth (dorso-ventral)} \times 100}{\text{cristal breadth}}$

3. *External conjugate index* (4 : 2) $\frac{\text{conjugata externa} \times 100}{\text{cristal breadth}}$

This index requires the presence of the fifth lunbar vertebra, and is therefore seldom possible. Its value consists mainly in its close correspondence to the same index on the living which is here one of the most important of the pelvic measurements. As the difference of this index in skeleton and in the living consists mainly in the addition of two thicknesses of integument to each measure, plus a slight reinforcement of fat added to the longer of the two, the proportions are kept almost exactly and there is probably less disparity in the index between the two conditions than in the length-breadth index of the head.

4. *Pelvic brim index* (8:10) $\frac{\text{upper sagit. diam. (conjugata vera)} \times 100}{\text{upper transverse diameter}}$

As classified by Turner* (1886) this index is divided into three groups:

brachypellic	below 90
mesopellic	90–95
dolichopellic	95+

Male Australians, Hottentots, and Andaman Islanders, are dolichopellic; male negroes are mesopellic; and male Eurcpeans, Hindus, Chinese, and American Indians are platypellic. The females are generally broader than their respective males, but in the South American Indians the males are platypellic and the females mesopellic (Turner).

5. *Coxal index* (17 : 14) $\frac{\text{breadth of ilium} \times 100}{\text{max. length of os coxæ}}$

6. *Iliac index* (17 : 16) $\frac{\text{breadth of ilium} \times 100}{\text{length (height) of ilium}}$

7. *Pubic index* (18 : 17) $\frac{\text{pubic length} \times 100}{\text{breadth of ilium}}$

8. *Ischiadic index* (19 : 14) $\frac{\text{length of ischium} \times 100}{\text{max. length of os coxæ}}$

9. *Obturator index* (24 : 23) $\frac{\text{transverse diam. of foramen} \times 100}{\text{vertical diam. of foramen}}$

* In Turner's original paper the middle group was called *mesatipellic*, as was then usual. The three classes were presented also in the reverse order. These have both been modified here to correspond to the general plan of the book. Turner also suggested, as alternate terms with the ones favored, those with the suffix-*lekanic*, instead of -*pellic*.

III. ANGLES

1. *Subpubic angle;* the angle formed by the two ischio-pubic rami, along their medial borders.

As is well-known the subpubic angle is a famous sex criterion, being small in the male and large in the female, which is true of all human races. Still, it may have a racial significance also, although the data thus far obtained are meager. Thus Turner, upon the basis of single individuals, where the sexes did not even correspond racially, are yet of some significance.

Males		Females	
Australian	47°	Negress	71°
Chinese	76°	Hawaiian	102°
Malay	76°	Lapplander	104°

Of these three males the average is 64°; of the three females 85°. Martin (1894) gives more complete data, from various sources:

Names of race	Males	Females
European	58°(Verneau)	76°(Martin)
		75° (Verneau)
		72 (Hennig)
Fuegian	60.5° (Martin)	85° (Martin)
	60.7° (Garson)	
	59° (Sergi)	81° (Sergi)
Australians		78°(Martin)
		80°(Verneau)
Andamanese		85° (Martin)

2. *Angle of inclination of the ilium.* This is the angle made by the plane of the ilium with the horizon, and may best be reckoned mathematically by the use of data already obtained from measurements, viz.—

cristal breadth (2)
upper transverse diameter of the pelvic brim (10)
length (height) of the ilium (16)

Nos. (2) and (10) are parallel to each other. (16) is set obliquely, connecting their ends. If the pelvis is perfectly symmetrical, which can by no means be taken for granted, these two parallel lines may be charted on a paper with their median points upon a common perpendicular which represents the median sagittal line. For complete accuracy the point in each line where it crosses the median plane should be noted in the measurement and these points, rather than the geometrical middle point, should be placed upon the perpendicular. In this way the exact inclination of each side can be either measured by the protractor upon the chart, or be reckoned by trigonometry from the data furnished.

3. *Divergence of the two ilia from each other.* This is nothing more than the sum of the previous angles as found for each side of a given pelvis, and is obtained by adding the two. It could also be obtained by some simple device which would measure this angle direct.

4. *Inclination angle of the pelvis as a whole.* This means the inclination of the conjugata vera to the spino-symphysial plane, or to the horizontal, which is the complement of the first. This angle is best measured direct upon the bones by some form of goniometer, the two legs resting upon the promontorium (in the median line) and the inner surface of the upper edge of the pubic arch. If the girdle be held in an osteophore from behind, and the vertical board used in orientation removed, the aspect required is quite exposed, and readily accessible to either the stationary or the clamp-on type of goniometer, by which the angle may be easily measured. For some methods of measurement a steel needle, fastened to the bone in such a way as to represent the conjugata vera, is of assistance.

5. *Sacral inclination angle.* This angle, which belongs more properly under the head of measurements of the sacrum, is the inclination of the sacral base to the spino-symphysial plane. The sacral base is the anterior surface of the body of the first sacral vertebra, which, in a complete girdle, is so closely fastened to the ilia, and intimately associated with them, that it serves as a base for the entire complex. This is measured by the goniometer, any form, upon a girdle properly oriented, and held in an osteophore applied dorsally. The measure ment is much assisted by first applying a steel needle to the surface of the base, along the median plane, and firmly fastened to the bone.

General considerations concerning angular measurements. In all angular measurements, both here and elsewhere, the actual obtaining of the values is a matter of individual ingenuity, in which there are always many possibilities. In general there are three kinds of methods, viz.:

(*a*) direct measurement on the bone, by some sort of goniometer
(*b*) charting the essential lines on paper, and measuring the angles thus obtained by means of a protractor
(*c*) getting the essential data by linear measurements, and reckoning the values of the angles involved by trigonometrical methods.

In many cases, where a single definite angle is receiving special attention, and where it therefore has to be measured again and again, the investigator has devised some special form of goniometer fitted to this particular purpose. This is to be generally encouraged, especially when the device is simple, but the modern tendency seems to be to reduce, rather than multiply, the number of different instruments, and to render those used more universal in their application. Thus, the calipers (craniometer) of the present time, and the pelvimeter, are practically identical in form, differing only in size, which is wholly a matter of convenience, and both are devised for use in cases where the two termini of a line frequently have some obstacle between them which has to be reached around in order to obtain a straight measurement. Again the slide-compass and the rod-compass are practically the same thing in two sizes, also for convenience; and these with the clamp-on goniometer the tape, and the anthropometer, of which the rod-compass is an adjustment, are all that is needed both for bones and the living, for all anthropometric uses except certain special work.

Aside from the sub-pubic angle, the difference in the value of which in the two sexes has long been known, the ossa coxæ with the sacrum exhibit other marked sexual differences, which may usually be relied upon in sexing a skeleton. These latter are especially practical when applied in the field during excavation, or in the case of incomplete skeletons, as they concern the single parts of which the girdle is composed and consequently do not require to have the pelvis put together as is the case with the subpubic angle.

The following are the most pronounced of the sex-determining characters of the separate ossa coxæ: *

1. *The curve of the iliac crest.* This is higher and more abrupt in the male; or, in other words, the outline presents the arc of a much smaller circle. It also turns down more abruptly dorsally.

2. *The shape of the sacro-sciatic notch.* This is narrow and deep in the male; shallow and wide in the female.

3. *The sulcus paraglenoidalis s. praeauricularis.* This is a groove, which runs over the inner surface of the ilium, just posterior to the auricular surface, and parallel to its posterior border. It is very variable in its appearance and occurrence, being generally absent in males, and present in females, with exceptions both ways. When well developed it is 2 cm. or more in length, and runs over the dorsal margin of the bone, so that it may sometimes be seen upon the outer side.†

4. *The acetabulum.*
   (*a*) This is larger in males; smaller in females.
   (*b*) In females it looks more forwards; in males more laterally. This character can be seen only in the complete pelvis.

Sacrum ‡

I. MEASUREMENTS

1. *Mid-ventral curved length;* the length of the median line, drawn along the ventral surface, from the median point in the anterior or margin

*There are also certain sex differences in the sacrum, which are noted in their proper place, below.

† For a recent discussion of the sulcus paraglenoidalis (praeauricularis) cf. DERRY, in *Journ. Anat. and Physiol.*, Vol. 43, 1909, pp. 266–276; see also LÖHR, in *Anat. Anz.*, Bd. IX, 1894.

‡ Cf. RADLAUER Beiträge zur Anatomie des Kreuzbeines. *Morphol. Jahrs.*, Bd. 38, 1908, pp. 323–447. This work was done at Zürich under Rudolf Martin, and is a complete analysis of the sacrum, treated anthropometrically and racially, according to the newest methods. The work may be taken as a standard and is largely followed here.

of the promontorium to that of the apex, without including the coccyx. (Fig. 37, the curved line *adb*). TM.

2. *Mid-ventral straight length* (length of sacral axis); the length of the straight line drawn between the two terminals employed in the previous measurement (the line *ab* in Fig. 37). SC.

3. *Anterior curved breadth;* the length of the line drawn perpendicular to (1), across the ventral surface of the first sacral vertebra, between the widest points of the margins of the lateral wings. TM.

4. *Anterior straight breadth;* the length of the straight line drawn between the two termini employed in (3). SC.

5. *Middle curved breadth;* the length of the line drawn perpendicular to (1), across the ventral surface, connecting the posterior angles of the wings as termini. These terminal points are practically at the level of the lowest point of the auricular surfaces, which can be used in cases where the lower angles of the wings are indefinite. TM.

6. *Middle straight breadth;* the straight line drawn between the termini employed in (5). SC.

7. *Lower breadth;* the distance between the posterior lateral angles, or, when these are not evident, the greatest breadth across the bone at the level of the most posterior pair of foramina. At this level the ventral surface of the bone is so flat that there is practically no difference between the straight and curved breadths. SC.

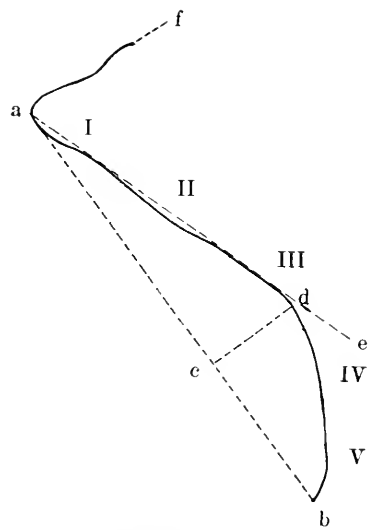

FIG. 37.—Median curve of sacrum. I–V, centra of vertebræ; a–b. mid-ventral curved length; c-d, maximum height of curvature. (*After Radlauer*)

8. *Maximum height of curvature*; the greatest distance between the two lines used in (1) and (2), measured on a line perpendicular with (2); i.e., the line *cd* in Fig. 37.

9. *Position of the maximum height line*; the relative position of the point *c* in Fig. 37, the foot of the perpendicular used in the previous measurement. The distance here measured is that from the promontorium to the foot of the perpendicular, the line *ac* of the figure above referred to. This figure is a profile projection of the median sagittal curve, and is drawn upon a properly oriented bone by means of a diagraph, precisely as in the corresponding craniogram described elsewhere. Several important sacral measurements may be measured upon it, such as Nos. 2, 8, and 9. These may be measured also directly upon the bone, and the two used to check each other. An instrument especially devised

for measurements 8 and 9 consists of two graded scales, set at right angles to each other. One spans the bone in the median line, and is placed in contact at the promontorium and the apex, while the other, which slides upon the first, and also lengthens and shortens, is adjusted as desired. When in the position *cd* its length, and its position on the base line, can be read off on the scales.*

10. *Antero-posterior (sagittal) diameter of the anterior articular surface;* the surface that articulates with the last lumbar vertebra. SC or TM

11. *Lateral (transverse) diameter of the same.* Nos 10 and 11 must be at right angles to each other. SC or TM

II. INDICES

(*a*) *Sacral indices; designed to show the general shape of the bone as a whole.*

1. *Sacral index A* (4 : 2) $\frac{\text{anterior straight breadth} \times 100}{\text{mid-ventral straight length}}$

2. *Sacral index B* (4 : 1) $\frac{\text{anterior straight breadth} \times 100}{\text{mid-ventral curved length}}$

Sacral index c (3 : 1) $\frac{\text{anterior curved breadth} \times 100}{\text{mid-ventral curved length}}$

Of the above three indices A is the classical one used by Turner; while B and C have the merit of expressing the full value of the vertebral axis, but have thus far been but little used. In these indices the sexual difference is marked, the breadth measures, and consequently the indices, being greater in females.†

The following values of Sacral index, A, have been found for various races, and appear here as compiled by Radlauer.

Racal Indices Sacral Index A

Name or race	Males	Females
Negtoes	91.4 (33)	103.6 (18)
Egyptians	94.3 (7)	99.1 (2)
Andamanese	94.8 (22)	103.4 (35)
Australians	100.2 (14)	110.0 (13)
Japanese	101.5 (37)	107.1 (36)
Europeans	102.9 (63)	112.4 (43)

* This instrument was devised by Radlauer and is figured by him in the article above cited (p. 336).

† With the exception of the ossa coxæ (innominata) there is no bone in the body more profoundly modified by sex than is the sacrum. The sex should thus be constantly regarded in all general averages, especially those which concern breadth of the bones, or the depth of curvature, and in conclusions connected with racial characteristics. Cf. Derry: The influence of sex on the position and composition of the Human Sacrum, in *Journ. Anat and Physiol.* (Engl.), 1912, pp. 184–192.

The numbers in parentheses give the number of individuals studied in each case.

Sacral indices like these are classified in three groups, with the following values:—

Index below 100	dolichohieric
Index between 100 and 106	subplatyhieric
Index above 106	platyhieric

In general, averaging both sexes, the narrowest sacra (dolichohieric) are those of Malays, Andamanese and Bushmen; sacra of middle proportions are possessed by many Caucasians, American Indians, Chinese, and Japanese; while wide sacra (platyhieric) occur among Australians and the Apline peoples of Europe. There are, however, in many cases, conflicting figures presented by different authorities, presumably because of the small numbers of individuals measured, in some cases only three or four.

(*b*) *Longitudinal curvature indices.*

4. *Curvature index A* (2 : 1) $\dfrac{\text{mid-ventral straight length} \times 100}{\text{mid-ventral curved length}}$

5. *Curnature index B* (8 : 2) $\dfrac{\text{maximum height of curvature} \times 100}{\text{mid-ventral straight length}}$

6. *Curvature index C* (9 : 2) $\dfrac{\text{position of maximum height line} \times 100}{\text{mid-ventral straight length}}$

These indices, devised by Radlauer, present the following values, although the number of individuals used is often too small for final conclusions.

Curvature Indices of Various Races

Name of race	Curvature index A.	Curvature index B.	Curvature index C.
Simian apes	98.7	9.6	42.9
Negroes	92.4	18.1	63.1
American Indians	91.6	19.5	72.5
Asiatics	89.7	20.0	67.2
Australians and Oceanians	93.1	20.8	48.8
Europeans	86.5	23.6	50.4

In index A the nearer the index approaches 100 the flatter is the longitudinal curve; in B the higher figures represent a deeper curve. Thus, in the Simian apes both the high index A and the low index B show that the longitudinal curve is slight, i.e., that the sacral axis is more nearly a straight one than in man. The position of the point of greatest curvature, as indicated by Index C, varies with the amount of curvature, lying farther back (more posteriorly) when the curve is deeper. This is indicated by the larger numbers, which show that the line *ac* is longer. In this particular the Fuegians have the highest number, and consequently the most posterior position of any race yet studied, modifying the general rule concerning the relation of curvature to position of the foot of the perpendicular, for in these people the actual amount of curvature, although great, is not quite that of the Europeans.

(*c*) *Transverse curvature indices.*

Transverse curvature index A (4 : 3) $\frac{\text{anterior straight breadth} \times 100}{\text{anterior curved breadth}}$

Transverse curvature index B (6 : 5) $\frac{\text{middle straight breadth} \times 100}{\text{middle curved breadth}}$

These two indices consist merely of comparisons of the straight and curved transverse diameters at respectively the anterior and middle parts of the sacrum, and indicate the amount of curvature, or longitudinal rolling, found in a given case. A similar index at the more posterior part of the sacrum has no especial meaning, as there the ventral surface of the bone is so flat that there is practically no difference between the two measurements. For these two indices the following racial values have been determined.

VALUES OF TRANSVERSE CURVATURE INDICES [RADLAUER, 394].

Name of Race	Transv. curv. index A	Transv. curv. index B
Lower apes	90.5	
Simian apes	97.1	97.3
Australians, Oceanians	94.8	97.3
Negroes	94.6	97.8
Asiatics	95.1	97.4
American Indians	95.3	97.9
Europeans	95.5	98.0

From these figures it will be seen that the sacrum is more nearly flat at about the middle than at the upper level; also that the European have the flattest sacra transversely, and the Australians and negroes the most curved, along the same aspect. Taken as racial criteria the slight difference shown here, which include the races of the greatest general difference, gives us little to hope for in the use of these indices. Probably the actual value of these transverse curvature indices is but slight.

(*d*) *Miscellaneous*

9. *Index of the sacral base* (10 : 11) $\frac{\text{sagittal diameter} \times 100}{\text{transverse diameter}}$

This index, a comparison of the two diameters of the anterior articular surface of the first sacral vertebra, (= Sacral base) has not yet been shown to be of much importance racially. It gives the relative shape of this flat surface, and range from 54.1 in the inhabitants of the Ural Mts. to 66.4 in the Burmese. The index for Europeans is estimated at 58.5, but for the Alpine peoples, at 58.7. In Negroes it is 61.2 and in Asiatics in general 62.6.

III. ANGLES

Promontory angle; this is the angle formed between the flat surface of the sacral basis and the beginning of the longitudinal curve of the ventral surface, as taken in the mid-ventral line. (angle *fae*, or *fac* in Fig. 37) This angle is the least in the Tyrolese, 58°; and the highest in Asiatics, averaging, 65°. In the Neolithic station at Schweizersbild are found sacra with a promontory angle of 70°, five degrees more than in any recent race.

The *sacral inclination angle* (No. 5 under Pelvic girdle, above) uses the plane of the sacral base for one of its sides, but, as it requires the spino-symphysial plane for the other, must be taken only on a complete girdle. Another form of the *Promontory angle*, which is in some ways more satisfactory than the one given here, might be made by using, with the same plane of the sacral base, the entire straight length line instead of the one indicating the anterior portion of the ventral surface, i.e., the line *ab* of Fig. 37 rather than the line *ae* of the same figure. This line seems not to have been used, and is hence not recommended here.

Other angles suggested, and occasionally used, are (1) the angle formed by the plane of the two auricular surfaces, usually meeting along an imaginary line posterior to the bone, and (2) the angle of inclination of the sacrum, or of the sacral axis, when the subject is standing. This latter, like that of the inclination of the pelvis as a whole, can be measured only upon the living subject, and then only approximately.

It might be possible, however, to relate the sacrum to some definitely determined plane in a properly articulated pelvic girdle, such as the spino-symphysial plane or that of the rim of the lower pelvis, and thus obtain proportions or relations of importance.

Anatomical variations in the sacrum, such as the number of the vertebræ which compose it, or the sacralization of the last lumbar vertebra, are mainly of biological interest, as are similar variations in other bones, and seem to have no racial significance.

VI. THE BONES OF THE LEG AND FOOT

Femur*

1. MEASUREMENTS

A. *Length*

Under this head four possible measurements may be taken, as follows:-

1. *Absolute length*; taken with the osteometric board. OB

2. *Physiological length*; this is the length used by Turner, and described by him as "taken in the oblique position". The two condyles are set upon a plane surface, and the length is then measured along a line perpendicular to this plane. This is taken with the osteometric board by placing the two condyles in contact with the fixed end. The shaft then lies obliquely in the trough of the board, and the moveable piece is shut down upon the head, thus measuring the greatest length obtainable with the bone in this position. This corresponds to the physiological, or efficient, length in the living limb. OB

3. *Trochanteric length*; from the most prominent point of the greater trochanter to the most distal point of the lateral condyle. This is an especially convenient measure, since it can be taken upon an articulated skeleton, or upon a fragmentary femur that has lost the head.

It can also be approximately determined upon the living subject. RC

Recent English work on this bone is that of Parsons; Characters of the English Thigh-bone (Journ. Anat. [English], Vol. 48, 1913–14; and Vol. 49, 1914–15). The author obtained his material from a crypt of the 13th and 14th Centuries, where the bones of some 33,000 persons had been interred, and thus had recourse to an enormous collection of bones of mediaeval Englishmen. Holtby in the same Journal (Vol. 52, 1918), gives a few additional data.

4. *Diaphysial length* (shaft-length); this uses as the two terminal points the upper end of the anterior intertrochanteric line, marked by a slight tubercle, and the middle of the anterior intercondyloid line, that is, its most proximal point. This may be measured by any suitable instrument; Lehmann-Nitsche uses a steel tape. RC or TM.

* A thorough analysis of the femur anthropometrically, both in the recent species, and in *H. primigenius*, is found in KLAATSCH's paper in Merkel and Bonnet's Anat. Ergebnisse, Bd. X. 1900. The special part treating of the femur is found on pp. 609–665. There is also an excellent bibliography of the subject to date. The full title is, Die wichtigsten Variationen am Skelet der freien unteren Extremitäten des Menschen, und ihre Bedeutung für das Abstammungsproblem.

Much of the pioneer work upon the femur, and the other long bones, was done by LEHMANN-NITSCHE in his investigation of the prehistoric "Reihengräber" skeletons Cf. for this, his "Untersuchungen über die langen Knochen der südbayerischen Reihengräberbevolkerung", in Beiträge zur Anthropol. u. Urgeschichte Bayerns. Bd. IX. 1895.

B. Shaft.

(a) Proximal shaft diameters SC or Cr.

5. *Dorso-ventral diameter of shaft*	At a point about 3 cm. distal to the lesser trochanter.
6. *Medio-lateral diameter of shaft*	

(b) Middle shaft diameters SC or Cr.

7. *Dorso-ventral diameter of shaft*	At the middle of the shaft.
8. *Medio-lateral diameter of shaft*	

(c) Circumference TM.

9. *Circumference of shaft at the middle;* taken at the same level as the two previous measurements.

C. Proximal end.

√ 10. *Oblique proximal breadth;* the greatest breadth of the proximal epiphysis, measured along the axis of the head and neck. This measurement is taken from the free surface of the head to the most lateral point on the surface of the greater trochanter. SC or RC.

11. *Length of head and neck;* from the free surface of the head to the center of the intertrochanteric line.

*12. *Vertical diameter of the head;* this is measured on the periphery and is the greatest diameter possible in this plane, which is parallel with the main axis of the shaft of the bone. SC.

13. *Transverse diameter of the head;* similar to the last but taken through a plane at right angles to the axis of the bone, and to the plane used in the previous measurement. SC.

14. *Circumference of the head;* taken around the largest place. TM.

15. *Vertical diameter of the neck;* taken across the neck, in the same plane as that used in measurement 12. SC.

16. *Transverse diameter of the neck;* taken across the neck, at right angles to the previous measurement; in the same plane as No. 13. SC.

17. *Circumference of the neck;* naturally the maximum circumference is intended. TM.

D. Distal end.

18. *Dorso-ventral diameter of the shaft just above the condyles.* For this a point in the middle of the flat area proximal to the condyles should

* Parsons (*Engl. Journ. Anat.*, 1913–14, p. 253) finds the diameter of the head of the femur of great use in sexing the bone, as this measurement is distinctly less in the female. Instead of using the vertical and transverse diameters, as recommended here (Nos. 12 and 13) the author uses the maximum diameter, which he finds by rotating the slide compass around the periphery of the head until he finds it (usually not far from the vertical line as here used). In English females this diameter is nearly always less than 45 mm.; in males of the same people it is in excess of 47 mm. In those few cases which are between these limits one cannot be certain about the sex. Cf. also, Dwight, in *Amer. Journ. Anat.*, Vol. IV, 1905, pp. 19–32.

be taken, about 4 cm. proximal to the line delimiting the articular surface. Cr.

19. *Medio-lateral diameter of the shaft just above the condyles.* This is to be taken at the same transverse level as No. 18, and should be at right angles with it. Cr.

20. *Greatest medio-lateral breadth across the epicondyles;* this is the greatest medio-lateral breadth of the lower end of the bone, and is ascertained by trial. It should be strictly lateral, and not passed obliquely from a ventral portion of one condyle to a dorsal portion of the other. OB; perhaps also SC or RC.

*21. *Greatest dorso-ventral length of the lateral condyle;* taken with the SC across the bone, at right angles to the axis. SC.

*22. *Greatest dorso-ventral length of the medial condyle;* taken in the same way as the preceding. SC.

* The significance of these last two measurements has been brought out in the comparison of the distal end of the femur in modern man and in the Neandertal species, as in the latter the lateral condyle is distinctly longer (deeper) than the medial one, while in the modern type the two are about equal. Thus, comparing the two although with a very few individuals concerned, we have the following:

Name of race	Length of lat. condyle	Length of med. condyle
Average of 25 modern femora; various races	60	55.3
European, No. 1	59	60
European, No. 2	62	61
Negrito	53	53
Neandertal (right)	70	67
Neandertal (left)	71	66
Spy 1 (right)	72	67

Again, by comparing the length of the lateral condyle (Measurement No. 21) with the length of the entire bone (here the trochanteric length, Measurement No. 3), the excessive length of the condyle in the Neandertals becomes at once apparent, thus:

Name of race	Trochanteric length	Length of lateral condyle
Negrito	390	53
Fuegians (8)	406.4	61.2
Veddah	425	60
Europeans (3)	443.3	64
Neandertal (right)	423	70
Neandertal (left)	425	71
Spy I (right)	410 (approx.)	72

II. INDICES

A. Caliber indices.

1. *Length-circumference index* (9 : 2) $\dfrac{\text{circum. of shaft at middle} \times 100}{\text{physiological length}}$

2. *Length-diameter index* (7 + 8 : 2) The "Robusticity index" $\dfrac{\text{sagit. + transverse diameters at middle of shaft} \times 100}{\text{physiological length}}$

B. Shape indices.

3. (proximal) *Platymeric index* (5 : 6) $\dfrac{\text{ant.-post. diam. of shaft. proximal} \times 100}{\text{transverse diam. at same point}}$

platymeric	below 85
eurymeric	85–100
stenomeric	100 +

4. (middle) *Pilastric index* (7 : 8) $\dfrac{\text{dorso-ventral diam. of shaft, at middle of the bone} \times 100}{\text{medio-lateral diam. at same point}}$

5. (distal) *Popliteal index* (18 : 19) $\dfrac{\text{dorso-ventral of shaft, just above the epicondyles} \times 100}{\text{medio-lateral diam. at same point}}$

C. Indices of proximal end.

6. *Head index A* (13 : 12) $\dfrac{\text{transverse diam. of head} \times 100}{\text{vertical diam. of head}}$

7. *Head index B* (13 + 12 : 2) "Robusticity index" $\dfrac{\text{transverse + vertical diameters of head} \times 100}{\text{physiological length}}$

8. *Neck-length index* (11 : 2) $\dfrac{\text{length of head and neck + 100}}{\text{physiological length}}$

D. Indices of distal end.

9. *Epicondylar breadth index* (20:2) $\dfrac{\text{greatest medio-lateral breadth across the epicondyles} \times 100}{\text{physiological length}}$

10. *Intercondylar index* (22 : 21) $\dfrac{\text{length of medial epicondyle} \times 100}{\text{length of lateral epicondyle}}$

11. *Condylar length index* (21: 2) $\dfrac{\text{length of lateral epicondyle} \times 100}{\text{physiological length}}$

Many of the indices above listed were at first devised to bring out more definitely certain differences already noted, which occur between man and the higher apes, or between modern man and the prehistoric *H. neandertalensis*, and hence like differences shown by measurements between the various human races may be found to have a developmental significance. Thus, the head of the femur is enormously large in the Neandertal type as compared with the modern species; and the difference in the shape of the shaft between the two human species and the gorilla is shown by the pilastric index. Other indices, indicate form-differences that have been in all probability brought about by habitual posture or habit, such as an habitual squatting as compared with sitting in chairs or upon stools. A few significant results as interesting in comparisons, may be given here.

Platymeric index (*No.* 3). Normal femora are always either platy- or eury-meric. Stenomeric femora seem always to be pathological. Among extremely platymeric peoples may be reckoned the Maori (63.6) the Hawaiians (65.4) and the Fuegians (66.9). The Hindu (72.6) and the Japanese (75.5) are moderately platymeric. The native Australians (82.2) and the Swiss (84.6) are almost eury-meric; and the Negroes (85.3), the French (88.2), and the Eskimo (88.3), are quite so. Ancient British skeletons, excavated in the neighborhood of the Roman wall, are very platymeric (67.7), while the modern British are more nearly eurymeric, with an average index of 81.8. This may suggest a partial substitution of race, or may be the result of a cultural change in the manner of resting, chairs vs. squatting.

Pilastric index (*No.* 4). This index is that of the two diameters of the bone, taken in the middle of the shaft, and is thus named from its inclusion of the longitudinal ridge or *pilaster*, which furnishes an attachment for certain of the large thigh muscles. This index is open to the objection that it is modified by the degree of development of the ridge, yet it shows considerable differences between modern man and the large apes, and may be considered of value. In general, in man, the shaft is in this region nearly circular, taken without the pilaster, and may thus be presumed to furnish an index of about 100. This the pilaster itself increases so that in all men an index of some over 100 is to be expected. The following indices have been found:

Australians	122.2
Veddah	122.1
Eskimo	118.4
Malay	114.7
N. Amer. Indians	112.4
Cro-Magnon	111.6
Maori	110.1
Negroes	108.0
French	107.8
South Germans	105.3
Fuegians	103.5
Japanese	100.0
Neandertal species (aver.)	99.0
Gorilla (5 femora; aver.)	78.0

Neck-length index (*No.* 8). In the exact form advised here there do not seem to be available figures as yet, but for two measurements very similar to those involved certain interesting figures are known. In these the trochanteric length (No. 3) and the total distance from the head to the outer margin of the bone are taken, which is very similar to our Measurement No. 10. The index can be readily calculated. The measures are generally those of single femora; those marked * are averages.

Name of race	Trochanteric length	Proximal breadth
Japanese	390	87
*Ainu	394.4	85.8
Javanese	400	94
*Fuegian	408.7	88
Malay	410	89
Gilbert Islander	420	96
*South Germans	428	91.5
Neandertal (right)	423	105
Neandertal (left)	425	106
Spy I	410 (approx.)	110

The markedly greater length of the proximal epiphysis in the Neandertal species, as compared with recent man, is here clearly shown. With a moderate trochanteric length the proximal breadth, that is, the length of the axis of head and neck, is far greater than is found in any normal femur of modern man. This is probably correlated in some way with the massiveness of the head of the femur in the earlier species.

Head index B; = Robusticity index of head (No. 7). This index should show the large size of the head in femora of the Neandertal species, since this peculiarity strikes the eye immediately, and is indicated by the following list of measurements. Although these give the absolute, instead of the physiological, length, the two differ but two or three millimeters as a rule, and indices using this length instead of the one recommended here, would show the contrast very decidedly. The figures, mostly of single measurements, are as follows:

Name of race	Absol. length	Vertical diam. of head		Transverse diam. of head	Circumference of head
Adamanese	375	....	36.1*		
Lapps	380.5	....	40.3*		
Hawaiian	404	....	39.0*		
Fuegians	427.1	45.9	.....	46.3	146.4
Alemanni (ancient)	436.6	44.3	.....	45.4	147
Neandertal (right)	439	50.5	.....	52.0	164
Neandertal (left)	440	52.0	.....	53.0	165
Spy 1 (right)	430 (approx.)	52.0	.....	53.0	175

In the figures marked * there is but one diameter given, and that one is not specified.

Here the Neandertals are best compared with the Alamanni, in which the absolute length is about the same, while the disparity in the dimensions of the head are evident. That this large and heavy head is in some way correlated with the great length of the proximal epiphysis, which includes head and neck, is highly probable.

III. ANGLES

1. *Collo-diaphysial angle.* This is the angle made by the axis of head and neck with that of the shaft (of the bone as a whole). It is usually measured by first placing steel needles along the bone to define the two axes, and then measuring the angle made by their intersection by means of a transparent, or other, protractor.

As this angle varies at different ages, becoming more nearly a right angle in senile femora, it should be used only through the middle part of life, from maturity to perhaps the 60th year. The angle differs markedly in the two human species, H. sapiens and H. neandertalensis, being much greater in the former. Thus in Germans it averages 125.9°, in Swiss, 133.°; and in Fuegians, 123.0°, while in Homo neandertalensis it varies between 115° and 120°.

2 *Condylo-diaphysial angle.* Stand several femora on the table, on their distal ends, resting both condyles on the surface, and with the bone extending vertically upward, and it will be noticed that the inclination of the bone to the surface of the table is not the same. This displays practically the condylo-diaphysial angle, which is the angle between a line drawn across the condyles distally and the axis of the shaft. As in the former case these lines are determined by the eye, and marked by steel needles, fixed to the bone by wax, or plastilene, while the angle is read off by a protractor. It may be also measured by means of a specially prepared osteometric board, upon which the bone is laid as in getting the physiological length. This angle has been determined at 8° in Fuegians, and 11° in Swiss. In H. neandertalensis it has been estimated at 9°, quite within the range of variation of modern men.

3 *Angle of torsion*; the angle formed by the axis of head and neck projected upon that of the condyles, and is measured in the same way as is the like-named angle in the humerus, by the parallelograph. If found to be easier the two axes may be marked by applying steel needles to the bone. The bone is then held vertically in a clamp, and the two axes are drawn as projections upon a piece of paper placed on the table underneath the suspended bone (see Fig. 11, p. 18).

This angle shows great individual variation, but may be of some racial value also. Thus Martin found in Fuegians a range of values between 6° and 38°, with a mean value of 18.3°. The right femur of the Neandertal skeleton has a torsion angle of 9.5°, and the same bone in Spy 1, shows a value of 12°.

IV. CURVATURE OF SHAFT

This character of the femur may be noticed incidentally by placing a series of femora on the table, dorsal side down, and lying in their natural position, when it will be noticed that the highest point of the convex curve of the ventral (anterior) surface differs considerably, i.e., that some femora lie flatter than others. This is a definite characteristic of the Neandertals, in whom the femora curve up strikingly higher than do those of the present living species.

No special apparatus has been devised to measure this with accuracy but by simply measuring the highest point of this curve by a ruler held vertically upon the table, and making an index with this as numerator and the physiological length as denominator. In this way the amount of curvature of individual bones may be easily compared.

Patella*

In spite of its small size, the patella is an important bone anthropometrically, as it is one of the parts, like the distal end of the femur, the proximal end of the tibia, and the bones of the ankle, which are concerned in the various methods of sitting and squatting, and are thus modified by the cultural environment of various races. These effects are largely seen on the dorsal (inner) surface, expressed in the articular surfaces; there are also differences in the relative size and shape of the entire bone. Yet, although these racial and individual differences have been recognized, very little actual work has as yet been done upon this bone, and the measurements proposed (e. g. Martin; Lehrbuch, pp. 930–31) are still mainly in the form of suggestion for future investigation.†

The articular surface of a patella is divisible into a number of facets, set at slightly different angles, reflecting the various habitual positions of the knee in different races and in different individuals. The most constant are (1) an inner and (2) an outer, of which the inner is much narrower, thus easily orientating the bone and distiguishing the left from the right. In some races there seem to be three such the third being placed between the first two. The outer one, also, is sometimes divided across into a larger upper, and a much smaller lower facet, as is seen in the Punjabi [Lamont, 1900]. The proportions of these facets may be readily expressed by the indices of the measurements of the maximum length and breadth of these separate facets.

Aside from the study of the facets there are the measurements of the bone as a whole. Martin (1914) gives the following measurements.–

1 *Maximum height*; taken along the main axis of the extended leg, from base to apex. SC.

* See a paper by J. C. Lamont in Jour. Anat. and Physiol., Vol. 44, 1910. This is upon the patella of the Punjabi and consists of two pages only, but is important.

† (See note at end of section on Tibia.).

2 *Maximum breadth*; across the bone from side to side, at right angles to the previous measurement. SC.

3 *Maximum thickness*; taken by placing the patella in the sagittal plane between the two arms of the slide compass. SC.

Then follow certain definite measures of the articular surfaces, which can be devised by the investigator in accordance with what he wishes to show. Martin suggests the height (proximo-distal) of the entire articular surface, and the breadth of the two lateral facets. For indices he suggests:–

1 *Height index;* this compares the height of the patella with the combined length of femur and tibia, and in order to make a comparison between two measurements of such different proportions, he takes a tenth of the latter measure, or, what is the same thing, multiplies the numerator (height of the patella) by 1000 instead of 100, thus

$$\frac{\text{Maximum height of patella (1)} \times 1000}{\text{length of femur} + \text{length of tibia}}$$

For definite values of this index he suggests,

low patella	below 50
medium height	50–55
high patella	55 +

2. *Breadth index*; he avoids dealing with such disparity in numbers by comparing the patellar breadth with the breadth of the femoral epicondyles, thus,

$$\frac{\text{maximum breadth of patella (2)} \times 100}{\text{epicondylar breadth of femur}}$$

values:

narrow patella	below 51
medium breadth	51–56
broad patella	56+

3. *Height-breadth index of patella*; this is simply the index of the two main dimensions of the patella, considered as a disc; measurements 1: 2, thus

$$\frac{\text{maximum height of patella} \times 100}{\text{maximum breadth of patella}}$$

Tibia

I. Measurements

A. Lengths.

1 *Maximum length* (*spino-malleolar*) measured with the inclusion of the intercondylar and malleolar spines, and hence possible on complete bones only. OB

2 *Maximum length* (*condylo-malleolar*); measured with the calipers

(pelvimeter) from the proximal articular surface (internal condyle) to the extreme end of the internal malleolus. PM

3 *Physiological length*; measured with calipers (pelvimeter) between articular surfaces and avoiding the projecting processes at either end; usually taken from the deepest point in the medial articular surface of the proximal end to the bottom of the hollow in the distal articular surface, just within the malleolus. PM

Lehmann-Nitsche, in his investigation of prehistoric German graves (Reihen-Gräber. 1895) uses the second maximum length, that is, the one without the intercondylar spine. Mollison (1908) uses the first and the third. Thus, for two Maori skeletons (right and left) he gives the following measurements:—

1 Spino-malleolar length	318	315	341	339
3 Condylo-astragal length (= "physiological")	294	294	312	311

B. Shaft.

4 *Dorso-ventral (sagittal) diameter* 5 *Medio-lateral (transverse) diameter*	Taken just below the level of the tuberosity. SC or CR.
6 *Dorso-ventral (sagittal) diameter* 7 *Medio-lateral (transverse) diameter*	Both taken at the level of the nutrient foramen, *i.e.*, at about the proximal third. SC or Cr.
8 *Dorso-ventral (sagittal) diameter* 9 *Medio-lateral (transverse) diameter*	Both taken at the middle of the shaft. SC or Cr.

10 *Circumference of the shaft (middle)*

11 *Least circumference of the shaft*; this place will be found somewhere in the distal fourth of the bone, generally about 10 cm. above the point of the malleolus. TM

12 *Proximal epiphysial breadth*; greatest medio-lateral breadth of the proximal end of the bone; the *bicondylar breadth*. SC

13 *Sagittal diameter of the distal epiphysis*; taken dorso-ventrally across the distal end of the bone. SC or Cr.

II. INDICES

1 *Platycnemic index* (7 : 6) $\frac{\text{medio-lat. diam. (nutr. for)} \times 100}{\text{dorso-ventral diam. (nutr. for)}}$

platycnemic	below 63
mesocnemic	63–70
eurycnemic	70 +

This index expresses the degree of *platycnemy*, or medio-lateral flatness, of a given tibia, a peculiarity which occurs sporadically in individuals of all races, and is practically constant in primitive peoples, and in ancient bones in general. Thus in Neolithic bones from French soil the range of the platycnemic indices runs from 61.5 to 65.4, while in the modern French the indices fall between 71 and 74. This may be a

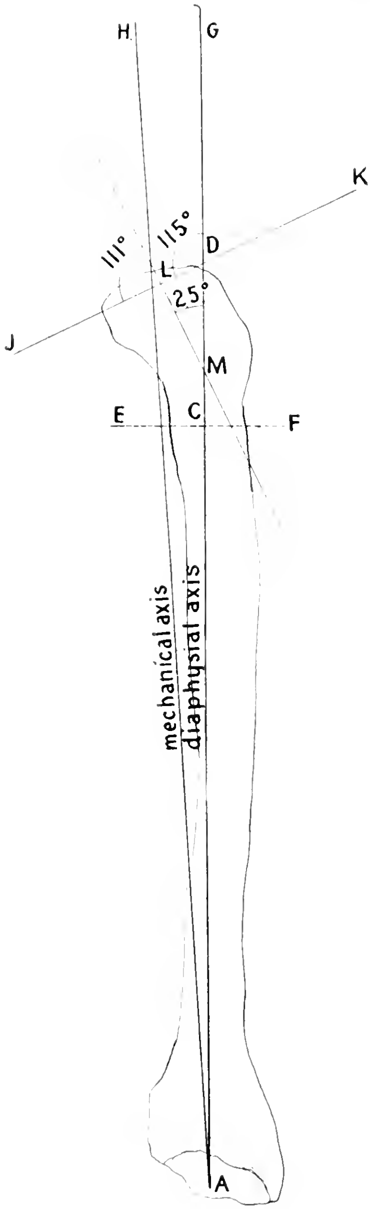

FIG. 38.—Profile drawing of the lateral aspect of the right tibia, to show certain axes and angles described in the text.
A–H, mechanical axis
A–G, plane of inclination of inner condyle
E–F, line drawn across shaft, about 2 cm. below the tuberosity, and crossing the two lateral contours of the bone, here indicated by heavy lines.
C, point where the line E–F, that part of it which is included within the contour lines of the shaft, is bisected.
The *inclination angle* is obtained by subtracting 90° from the angle JLH.
The *retroversion angle* is obtained by subtracting 90° from the angle JDG, which is the same as the angle LMD. This figure was projected from the right tibia of an Australian male, and this gives the actual figures for an actual case.

cultural modification due to the resting posture, squatting vs. sitting in a chair. [cf. Note below].

2. *Caliber index* (11 : 1) $\dfrac{\text{least circumference of shaft} \times 100}{\text{maximum length}}$

III. ANGLES

1 *Retroversion angle*
2 *Inclination angle*
3 *Biaxial angles*

These angles are involved in the description of the noticeable bend which the upper end of the tibia makes with the remainder of the shaft, best seen when the bone is in profile. They are best measured with a protractor upon a projection on a sheet of paper, drawn from a bone placed horizontally above it, with the lateral (outer) aspect uppermost. Certain essential points and lines are first located on the bone and then projected upon the paper.

The termini of the *mechanical axis* are first determined as follows, and marked on the bone with a pencil. The proximal point is the center of the deepest portion of the articular surface of the inner condyle, (*B*) and the distal one is in the middle of the very slight ridge that runs sagitally across the distal articular surface (*A*). The line drawn through these is the mechanical axis. The next is the determination of the *plane of inclination* of the articular surface of the medial condyle, which is effected by placing a steel needle tangent to the surface and in a dorso-ventral direction, and fixing it in the desired position with wax. (JK)

When these preliminaries are done the bone is placed in a horizontal position above a large sheet of paper lying on the table, with the lateral (outer) surface facing directly upwards, and the essential points projected upon the paper, precisely beneath its position on the bone. The holding of the bone may be effected by means of a clamp upon an iron retort stand, and the projections drawn by diagraph or parallelograph. Indeed, a fairly accurate projection may be made by placing the bone almost in contact with the paper, and then tracing around it with a pencil from which the wood upon one side has been whittled away. The pencil must be held perpendicularly. This need not be a complete contour tracing, but must include the accurate locating of the two points in the two articular surfaces above mentioned, two points along the course of the steel needle, as far apart as convenient, and bits of the contour of the sides of the shaft in the vicinity of the nutrient foramen.

When these points are located, connecting lines are drawn through and between these as follows:—(see Fig. 38)

(*a*) *The mechanical axis*; from the distal articular point, A, to the proximal one, B.

(*b*) *The line EF*, directly across the shaft, about 2 cm below (distal to) the tuberosity nurti. This line, limited at both sides by the shaft contours, is bisected at C, which is the point sought.

(*c*) *The diaphysial axis*; drawn from the point A, in common with the former axis, through the point C, coming out proximately wherever it may. (here, in the figure, at D) (*d*) The *line of inclination of the inner condyle,* which is that of the steel needle; found by connecting the two points already located in the projection. Naturally these may be placed anywhere along the needle, but the line is more accurate the farther apart they are. JK.

The three angles above listed are thus constructed, and now have merely to be read off, thus:—

1 *Retroversion angle;* the angle JDG is measured for this, after which 90° are subtracted. This gives the value of the true retroversion angle, LMD, which is that between the axis of the retroverted proximal end (at right angles to the inclination of the face of the condyle) and the diaphysial axis.

2 *Inclination angle* HLK, the angle of inclination of the face of the inner condyle, compared with that of the mechanical axis of the entire bone. Here also 90° are to be subtracted.

3 *Biaxial angle;* that between the two long axes here used, mechanical and diaphysical, HAG. Its value is that of the difference between the two preceding angles, of reversion and inclination. Thus, in the diagram here shown, Fig. 38, the first is 25°, the second 21°, and the biaxial 4°.

The reason for using the plane of inclination of the proximal articular surface is that it is at right angles to the axis of the short proximal part, the angle of retroversion of which is sought, and that it can be placed in a projection with considerable precision, while there is little to use in placing a definite axis to this short part. This large surface is, however, at right angles to the axis sought, and hence its angle may be measured and then reduced by 90°. Should the investigator so desire, he might ascertain the axis of each part as he best can by estimation, fix steel needles to both, and measure the angle between them direct on the bone, as in similar cases.

The value of this retroversion angle has been found to vary from 0° in an ancient French skeleton to 30° in a California Indian, but is usually, in European skeletons, between 15 and 20°. The diagram given here where the angle of retroversion is 25°, is taken from an Australian.

A considerable retroversion of the tibia is the usual fetal condition, even in Europeans, and is retained during infancy. In other words it is a universal human condition of human tibiæ at birth, and is retained by certain of the lower races, but is generally outgrown by Europeans.

4. *Angle of torsion;* as with such bones as the humerus and the femur, this angle is made by the lateral axes of the two ends of the bone, projected upon each other in a bone held perpendicular to the paper. The proximal axis passes through the two condyles, at right angles to what is judged to be the sagittal plane, and the distal axis is drawn across the articular surface from the point of the inner malleolus to the opposite side, as in the case of the radius. Little has been done with this angle

within recent years, but Miculiez in 1878 determined its usual value as lying between 5 and 20°, with extremes of 0° and 48°.

IV. SPECIAL FEATURES

The profile of the articular surface of the lateral condyle, as seen from from the lateral side, has been found to vary markedly in certain human races, although it is a character which cannot be easily expressed by measurements. At one extreme of the series of outlines which this surface presents we find one that is almost a plane, or even slightly convex; the series then passes through the various stages of a slight or a considerable convexity, becoming decidedly rounded at the other end of the series. This last is found among individual Andamanese, although it is by no means a general character.

A modification at the distal end, which must be taken in connection with corresponding ones in the talus, which articulates with it. It consists of the extension of the articular surface forwards (i.e., ventrally) especially along the medial side, and is plainly a modification due to an extreme flexed position of the foot upon the leg, in the position of squatting. This is one of the most simple and easily noticed modifications correlated with posture, and should be studied in connection with several others noticed here. As expressed by one of the latest investigators on the subject, Havelock Charles, "The history of the influence of the chair upon the tibia has got to be written." Such studies of the correlation of the details of the bones and certain habitual actions and postures has not only a fundamental biological interest, but will allow the investigator to obtain numerous details concerning the daily life and activities of prehistoric peoples, written in definite, though as yet unknown characters upon their bones.*

* The following papers deal directly with the influence of habitual posture upon the bones of the lower limbs, and the results are deduced mainly by comparison of Europeans with races like the Punjabi of India, who in a resting position squat upon their heels without coming in contact with the ground. Such a posture induces an extreme flexion at hip, knee and ankle, and naturally modifies the articular surfaces and other characters.

THOMSON, A.: The influence of posture on the form of the articular surfaces of the Tibia and Astragalus in the different races of men and the higher apes. *Journ. Anat. and Physiol.*, XXIII, N. S. Vol. III, 1889.

THOMSON, A.: Additional note on the influence of posture, etc. *Journ. Anat. and Physiol.*, XXIV, N. S. IV, 1890.

CHARLES H.: The influence of function as exemplified in the morphology of the lower extremity of the Punjabi. *Journ. Anat. and Physiol.*, XXVIII, N. S. XIII, 1894.

CHARLES H.: Morphological peculiarities in the Punjabi and their bearing on the question of the transmission of acquired characters. *Journ. Anat. and Physiol.*, XXVIII, 1894.

LAMONT, J. C.; Note on the influence of posture on the facets of the patella. *Journ. Anat. and Physiol.*, Vol. XLIV, 1900.

The Fibula

I. MEASUREMENTS

1. *Absolute length;* taken with the osteometric board. Only to be taken in bones with the two ends perfect. OB.
2. *Circumference of the middle of the shaft.* TM.
3. *Least circumference.* TM.

II. INDICES

1. *Caliber index* (3 : 1) $\frac{\text{least circumference} \times 100}{\text{absolute length}}$

This bone has thus far been studied anthropometrically but very little and yet, as the bone is easily modified by the usual position of the leg, both in sitting, standing, and walking, it is very probable that striking differences, both morphological and cultural, will be revealed to future study. It is an excellent bone to recommend for future work. Thus, as a beginning, Martin has noticed its absolute straightness in Fuegians in contrast to the curve seen in Europeans, the concavity being forward. Klaatsch correlates a straight fibula with a large degree of tibial reversion, the two occurring together in legs the feet of which rest largely along their outer edges, as in apes and infants. The correction of the tibia, by which the proximal end is brought forward affects also the fibula, which is attached to it, bringing its proximal end also forward, and giving the entire bone a light curve. There is also some variation of the relative position of the two lower leg bones, as is seen by comparing on several tibiæ the actual position of the facets for the fibula. Thus the fibula of the Spy skeletons was placed upon the tibia more as is that of the present-day Mongolian. The neandertaloid fibula seems to indicate that the foot came in this species in contact with the ground more along the outer edge than in modern man, and that the modern correction has tended to shorten the length and reduce the caliber, of the whole bone.

The Foot Skeleton in General*

As the human foot has been subject to much more profound modifications than the hand in changing from the typical anthropoid condition, so is the study of its proportions of more importance. Many of its peculiar-

* *For the foot skeleton in general*, cf.

Volkov, Th.; Les variations squelettiques du pied chez les Primates et dans les races humaines. *Bull. et Mem. de la Soc. d'Anthropol. de Paris.* 1905.

Lazarus, S. P.; Zur Morphologie des Fuss-skelets. *Morph. Jahrb.*, Bd. XXIV, 1896.

Adachi, B. und Mme. Adachi: Die Fussknochen der Japaner. *Mitt. der med. Fak. der Univ. Tokio.* 1905.

Uhlbach, R.; Messungen an Hand-und Fuss-skelet von Hottentotten. Zeitschr. *Morph. und Anthropol.*, Bd. XVI, Jan., 1914.

ities are due to morphological causes; others to cultural ones. The first considers the gradual shaping of an arboreal foot from a climbing, prehensile organ, to a firm platform for walking upon the ground, changes which are largely due to the shaping of the peroneal muscles for lifting the outer edge, and in part also to the giving up by the first digit of the most of its prehensile function, and the gaining of greater size and strength for the application of force in a new direction. The second, or cultural, changes, are the result in part of the introduction of new methods of sitting, standing, and walking, and in part modified by the introduction of various types of shoes and sandals.

Aside from the study of the foot as a whole, several of the separate bones deserve special treatment, especially the talus, which forms the main articulation with the tibia, and is thus concerned in all general acts, such as walking. Next in importance come calcaneus and naviculare, which have already been the subject of anthropometric research, while the remaining bones have been studied mainly in relation to the shape of the entire foot. These three specially named bones are here treated in detail, after which the foot is considered as a whole.

Talus

Orientation.—The bone is to be first placed on a table, with the trochlear surface uppermost, and with the navicular head towards the observer. The bottom of the trochlear groove, which is almost a straight line may be marked with a pencil, and gives approximately the location of the *sagittal axis* (SS in Fig. 38). The *transverse axis* (TT) runs across the middle of the trochlea, at right angles to the sagittal axis. As the navicular head forms, with its neck, a distinct portion of the bone, the *collum tali*, it may be considered to have its own axis, as drawn by the eye through the middle of this portion, beginning at the center of the

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HASEBE, K.; Ueber die Häufigkeit der Coalescenzen, etc., der Fussknochen der Japaner. *Zeitschr. Morph. und Anthropol.*, Bd. XIV, 1912.

For separate tarsal bones, cf.

REICHER, M.; Beitrag zur Anthropologie des Calcaneus. *Archiv. f. Anthropol.*, N. F. Bd. XII, 1913, pp. 108–133.

SEWELL, SEYMOUR; A study of the astragalus. *Journ. Anat. and Physiol.* (Engl.) Apr., 1904; July, 1904; Oct., 1904; Jan., 1906.

MANNERS-SMITH; A study of the navicular in the human and anthropoid foot. *Journ. Anat. and Physiol.* (Engl.), 1907.

MANNERS-SMITH; A study of the Cuboid and Os peroneum in the human foot. *Journ. Anat. and Physiol.* (Engl.), 1907.

For relations of foot bones in the same foot, cf.

PFITZNER, W.; Beiträgen zur Kenntniss des menschlichen Extremitäten skelets. A series of papers in the *Morphol. Arbeiten*, especially, No. VII, Die Variationen im Aufbau des Fuss-skelets, Bd. VI, 1896. This paper presents a summary of the details obtained from more than a thousand human feet, personally prepared by the author in order to prevent any possible confusion. Cf. also the work of this author, in the same series, on the hand.

VIRCHOW, H.; Die Aufstellung des Fuss-skelet. *Anat. Anz.*, Bd. VII, 1892.

articulation with the navicular bone. This axis (ac) makes an important angle with the sagittal axis, the angle of the collum (acS). Oriented in this way the talus presents the usual six aspects, or norms, of which the most important are (1) the *norma trochlearis,* (Fig. 38); (2) the *norma basilaris,* which is in contact with the calcaneus (Fig. 39); and (3) the *norma frontalis,* or *distalis,* in contact with the naviculare (Fig. 40).

I. MEASUREMENTS

1. *Length;* greatest length obtainable between the bottom of the sulcus for the tendon of *Flexor hallucis longus* and the furthest point on the surface of the navicular head; the line *ab* in Fig. 39. SC or Cr.

2. *Breadth;* from the furthest lateral point of the lateral process, in the transverse axis, to the opposite side (Te in Fig. 39). SC or Cr.

3. *Height;* the distance of the highest point in the trochlear groove from the table on which the bone rests (*cd* in Fig. 40). This measurement is best taken by holding the bone upon a glass plate of known thickness, say one millimeter, measuring the distance from the upper point through to the lower surface of the glass plate, and then subtracting the thickness of the glass. SC or Cr.

4. *Length of the trochlea;* measured with the slide compass along the sagittal axis, between the borders of the articular surface. SC.

5. *Breadth of the trochlea;* measured with the slide compass along the transverse axis, between the borders of the articular surface. SC.

6. *Length of the head* (*caput tali*); total length of the articular surface covering the head, using as termini the ends of the longitudinal axis of this surface. SC.

7. *Breadth of the head* (*caput tali*); total breadth of this surface, taken at right angles to the above. SC.

8. *Length of the posterior articular surface for the calcaneus* (*ab* in Fig. 39); taken along the longitudinal axis of this surface SC.

9. *Breadth of the posterior articular surface for the calcaneus* (*cd* in Fig. 39); taken at right angles to the previous measurement. SC.

II. INDICES

1. *Length-breadth index* (2 : 1) $\frac{\text{breadth of the bone} \times 100}{\text{length of the bone}}$

2. *Length-height index* (3 : 1) $\frac{\text{height of the bone} \times 100}{\text{length of the bone}}$

3. *Trocheal length index* (4 : 1) $\frac{\text{length of trochlea} \times 100}{\text{length of the bone}}$

4. *Length-breadth index of posterior calcanear articulation* (9 : 8) $\frac{\text{breadth of the post. calcan. artic.} \times 100}{\text{length of the same}}$

5. *Length breadth index of the head* (7 : 6) $\frac{\text{breadth of the head} \times 100}{\text{length of the head}}$

III. ANGLES

1 *Angle of inclination of the collum tali;* the angle between the axis of the neck and the sagittal axis of the bone (as in Fig. 38).

2. *Angle of torsion of the head;* the angle between the longitudinal axis

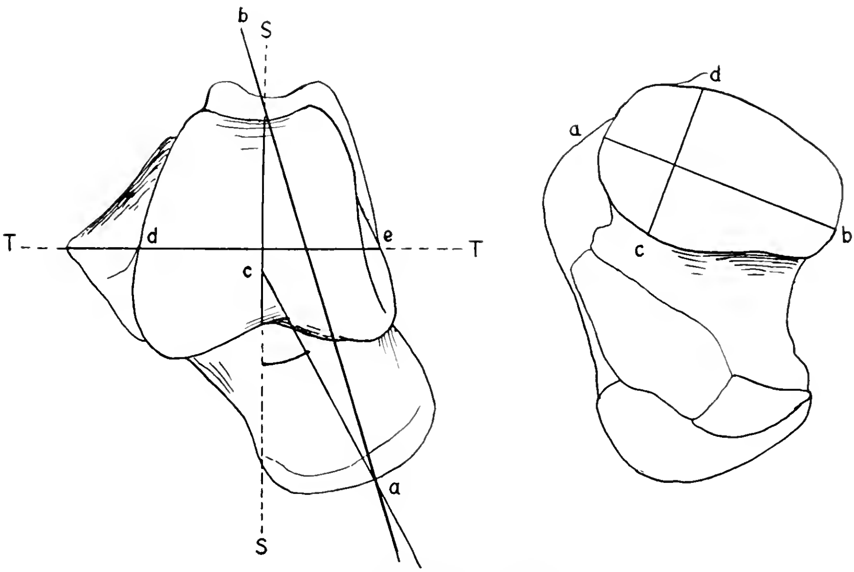

FIG. 39.—(*After Seymour Sewell*).

of the head, and the plane placed tangent to the highest points of the trochlea (*efg* in Fig. 40).

3. *Angle of inclination of the posterior articular facet;* this is the angle formed between the sagittal axis of the bone (*i.e.*, the line of the trochlear

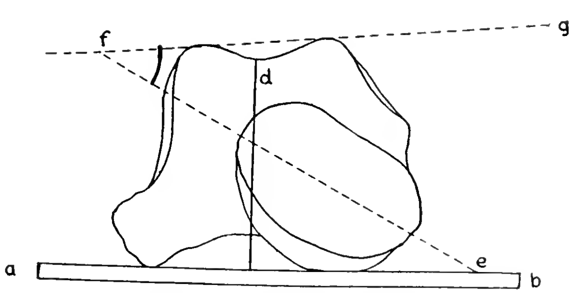

FIG. 40.—(*After Seymour Sewell*).

trough) and the long axis of the posterior facet (SS, Fig. 38 with *ab*, Fig. 39). As these two are not only in different planes, but also upon opposite sides of the bone it is clear that the angle must be formed by projection, which is accomplished in a practical way as follows. Steel needles are applied to the surface of the bone, the one defining the longitudinal axis of the trochlea, the other that of the posterior facet; a third one is then placed upon the trochlear surface, crossing the needle which defines the axis, and placed parallel to the needle upon the posterior facet, which can be done by the help of the projecting endso this needle. The angle thus formed by the intersection of the two needles in contact may then be read off by the transparent protractor.

Calcaneus

The technique of the anthropometry of the calcaneus, as given here, consists of the more important of the measurements proposed by Reicher, in 1913 (Archiv für Anthropol. XII, pp. 108–133). This work was done at Zurich under Martin, who has also incorporated Reicher's results in his text book (1914).

I. MEASUREMENTS

1. *Maximum length;* the length of the longitudinal axis of the bone, which runs through the most backward projecting point of the tuber

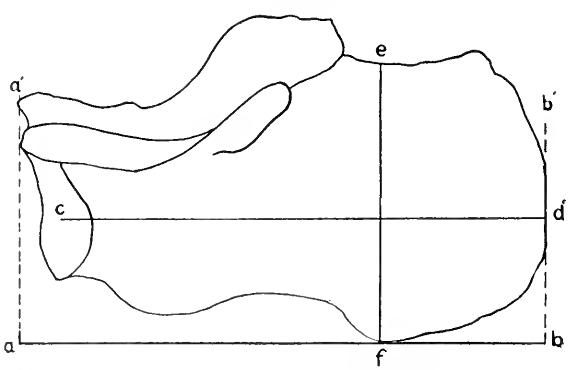

FIG. 41.—Right calcaneus, medial view, showing lines for measurement. (*After Reicher.*)

calcanei, and the middle of the upper edge of the articular surface for the cuboid. There is a slight difference between this measure, taken directly, as done by Volkov (1904), and by Reicher and Martin, who take it projectively, dropping the two points down upon the surface upon which the bone lies (line *ab* in Fig. 41, dropped from *a′* and *b′* or *d*). The line *a′d* would be oblique, and hence a little longer than *ab*. Reicher mentions also what is really the physiologica, or working, length, which ends anteriorly in the center of the cuboid articulation, *i.e.*, the line *cd* in Fig. 41. SC.

2. *Breadth across the sustentaculum;* this is taken across the sustentaculum to the most lateral point in the border of the posterior articular surface for the talus, along a line at right angles to the longitudinal axis and upon a horizontal plane, perpendicular to the sagittal plane, that is involving a double projection (line *ab* in Fig. 42). This measurement is

not really difficult to take, as the two arms of the slide compass, as long, parallel rods, may be placed parallel with the longitudinal axis of the bone, and in an approximately horizontal plane. SC.

3. *Least breadth of the body of the bone;* this is taken, with the slide compass held transversely to the longitudinal axis and enclosing the narrowed portion of the bone, just anterior to the tuber calcanei, and immediately behind the posterior articular surface for the talus. SC.

4. *Height of the body;* this is the distance from the bottom of the slight depression between the raised upper edge of the tuber calcanei and a similar one at the back of the posterior articular facet for the talus, and the substratum upon which the bone is resting. It is best measured, as in the case of the talus, by holding the bone in the proper position upon a glass plate of known thickness, taking the measure through both glass and bone, and then subtracting the thickness of the glass plate (see measurement 3 under Talus; Fig. 40). The measurement, without the glass plate, is shown as the line *cf* in Fig. 41. Cr or SC.

5. *Length of the body of the calcaneus* (= the effective length of the heel); this is the length, taken along the longitudinal axis, from the most backward projecting point on the tuber to the most anterior point of the anterior margin of the posterior articular surface for the talus (line *cc'* of Fig. 42). SC.

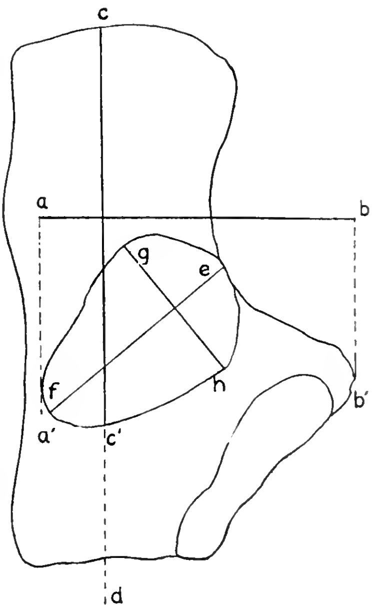

FIG. 42.—Right calcaneus, from above, showing lines for measurement. (*After Reicher.*)

6. *Breadth of the sustentaculum;* taken from the most laterally projecting point of the sustentaculum, at right angles to the longitudinal axis, to the medial edge of the sulcus for the tendon of the Flexor hallucis longus. This is a very uncertain measure, unless the line is taken exactly at right angles to the longitudinal axes, as the medial limit is placed upon an oblique line, which changes its relationship to the lateral one at every point.

7. *Height of the tuber calcanei;* taken sagittally through the tuber from the highest point above to the lowest point in the medial tuberal process, as far anteriorly as possible. SC or Cr.

8. *Breadth of the tuber calcanei;* taken across the tuber, at right angles to the previous one; the maximum breadth. SC or Cr.

9 and 10. *Length and Breadth respectively of the posterior articular surface for the talus.* (Fig. 42, *cf* and *gh*). SC.

II. INDICES

1. *Length-breadth index A* (2 : 1) $\frac{\text{breadth across sustentaculum} \times 100}{\text{maximum length}}$

2. *Length-breadth index B* (3 : 1) $\frac{\text{least breadth of body} \times 100}{\text{maximum length}}$

3. *Length-height index* (4 : 1) $\frac{\text{height of body} \times 100}{\text{maximum length}}$

4. *Calcar length index* (5 : 1) $\frac{\text{length of the body (heel length)} \times 100}{\text{maximum length}}$

5. *Tuberal index* (8 : 7) $\frac{\text{breadth of the tuber} \times 100}{\text{length of the tuber}}$

6. *Index of the posterior articular facet* (10 : 9)*

$$\frac{\text{breadth of post. art. facet} \times 100}{\text{length of post. art. facet}}$$

III. ANGLES

1. *Angle of inclination of the posterior articular facet;* this is the angle between the longitudinal axis of the facet in question and that of the bone as a whole (*cd* and *ef* of Fig. 42). It is taken by fixing steel needles in the proper places and reading the result by means of a protractor.

2. *Talo-calcaneus angle;* this is an angle involving the relative position of the two bones considered, and differences in it are indicative of differences in the habitual position, and consequently in the use, of the foot. It is really the angle formed between the longitudinal axis of the calcaneus and that of the talus, through the trochlear trough, but is best obtained by subtracting the angle of inclination of the posterior facet of the talus from the corresponding angle on the calaneus (angle 3 of the talus from angle 1 of the calcaneus). This procedure assumes a complete coincidence of the two posterior facets with their longitudinal axes, from which the varying longitudinal axes of the two bones are laid off at definite though different angles. The difference between these two, as measured from the same plane, is the value of the angle sought.

The Other Tarsal Bones.

The remaining tarsal bones, especially cuboid and naviculare, have been subjected to certain special anthropometrical measurements, upon lines similar to those already laid down for the others. These consist of lengths, breadths, and heights, the axes of important articular facets, also indices expressing the relationships of these. The two first-men-

* Besides the above there have been used (1) the index between the length of the sustentaculum and the breadth of the entire region, and (2) the length and breadth of the cuboid articulation, with the index between them. The first would seem to require an almost impossible accuracy in the length measurement; the latter is too uncertain in many ways. However, these results may be consulted in the original paper, above referred to.

tioned bones have been considered by Manners-Smith in the Journal of Anatomy (Engl.), 1907–1908, to which the reader is referred.

The Metacarpals and Phalanges.

In these bones, as in the hand, the most obvious measurements are, first of all, the total lengths of the separate bones, and then the breadths of the two epiphyses and the middle of the shaft, also certain of the girths especially the least circumferences. For these it is obvious that some very

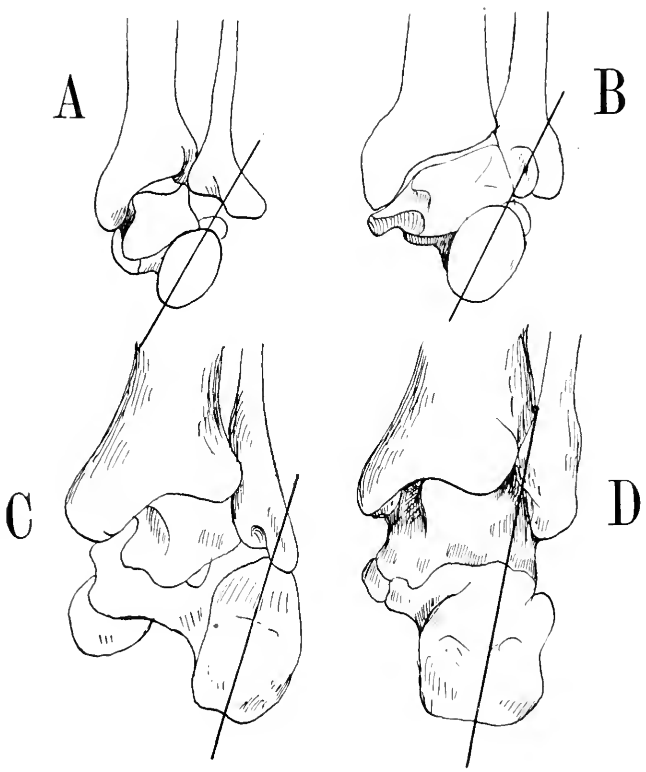

Fig. 43.—Torsion of the calcaneus, in various Primates. (*From Loth, after Volkov.*)
A. Chimpanzee.
B. Gorilla.
C. Australian.
D. European.

delicate method of measurement should be devised, such as, for example, the use of fine wire, as employed by dentists in getting the caliber of a tooth.

As for indices, aside from those derived from the measurements of single bones there are obviously collective indices obtained by adding certain similar measurements of a series of bones, for example, the entire breadth of the foot at a given point might be represented by adding the breadths of the proximal epiphyses of all five metatarsals, and this combined breadth might very well be compared with a combined length, such as those of the metatarsal, first, and second phalanges of digit I. Thus the two following indices have been suggested and employed to some extent.

$$\textit{Foot index } \frac{\text{breadth of metatarsals I–V (proximal)} \times 100}{\text{length of digit I; metatarsal; phal. 1; phal 2}}$$

$$\textit{Plantar index } \frac{\text{breadth of metatarsals I–V (proximal)} \times 100}{\text{length of metatarsal I}}$$

As in the case of the knee, so the ankle joint, with the reciprocal action of the various articular facets of the several bones involved is of great importance in the study of habitual posture, and possible racial differences due to environment and habit (see above, under Patella, Femur, Tibia, etc). A noticeable angle, as seen from behind, is that first pointed out by Volkov (1905) [Fig. 43]. For measuring this the entire set of the bones involved must be accurately placed together as in life, a feat impossible of accomplishment save by special treatment of single specimens,* but the results show beautifully that the human foot has descended from one whose sole was turned obliquely inwards, and that certain of the races yet living have not progressed as far as the Europeans in rectifying this. The four figures presented show the foot skeleton in a natural position as seen from directly behind. The longer axis of the tuber calcanei is indicated in all cases by a line, the inclination of which to the long axis of the leg shows the habitual foot position. The plane of the sole is in all cases set at right angles to this line. The tuberal axis is thus in the chimpanzee (A) seen to be set at about 30° from the perpendicular, in the gorilla (B) somewhat less; in the Veddahs from Ceylon (C) the line approaches the perpendicular, and in the European (D) this point is nearly attained.

The changes shown here phylogenetically appear in succession in the first two or three years of life in the human infant, who passes through all the stages in the gradual straightening of the feet for erect walking, from the extreme simian position at first to the characteristic adult condition. The use of both the feet and legs, as well as their frequent postures, give many an indication of early conditions, when these members possessed a more prehensile function than in the recent species.

Intermembral Indices

Intermembral indices, as used thus far, concern the lengths of the four principal lengths of arm and leg, as represented by *humerus*, *radius*, *femur*, and *tibia*, and express the various relations shown between them by the use of a certain one as a standard. The particular lengths recommended in this work are the following:–

*See H. Virchow: Die Aufstellung der Fuss-skelets, in *Anat. Anz.*, VII, 1892.

Humerus; Greatest length (1), as taken with the osteometric board OB.

Radius; Physiological length (2); from the center of the capitellar depression proximally to the center of the slight ridge which crosses the distal articulation transversely. Cr or SC

Femur; Physiological length (2); as taken with the osteometric board, and with the two condyles in contact with the transverse plane. OB.

Tibia; Physiological length (3); from the deepest point in the articular surface of the medial condyle to the deepest point in the distal articular surface just within the medial malleolus. Cr or SC.

The following indices are in common use:–

1 *Radio-humeral index* $\frac{\text{radius length} \times 100}{\text{humerus length}}$

This is an old index, formerly much used notably by Broca in 1862, and by Turner in 1886. In both cases the greatest lengths were used, and the arms (radii) were classified as follows:

Index below 75	brachycercic
75 to 79	mesaticercic (mesocercic)
Index above 79	dolichocercic

Europeans, Lapps, Eskimo, and Bushmen are brachycercic; Australians, Negroes, Hindu, Chinese, and American Indians, except Fuegians, are mesocercic; Andamanese, Negritoes, and Fuegians, are dolichocercic.

2 *Tibio-femoral index* $\frac{\text{tibial length} \times 100}{\text{femoral length}}$

This index corresponds exactly to the previous one, being for the leg what that is for the arm, i.e., a proportionate measure for the distal joint.

These indices are classified into two groups by the boundary number 83, all indices below this being *brachycnemic;* all above it *dolichocnemic.* To the first belong the Europeans, Chinese, Tatars, Lapps, and Eskimo; to the latter the Australians, Negroes, Andamanese, and American Indians.

3 *Intermembral index* $\frac{\text{length of humerus} + \text{radius} \times 100}{\text{length of femur} + \text{tibia}}$

For this, both Turner (1886) and Martin (1893) used the maximum lengths of all the bones concerned, as ascertained by the osteometric board, but the differences between these results and those obtained by the more exact physiological lengths are but slight, and the data thus obtained may be considered as practically correct. For comparisons involving both bones and the living, however, the physiological lengths should be used, as the two may then be closely compared, or even used interchangeably. The most important results of the two investigators mentioned are as follows, remembering that, unless there is much disparity in leg-length, a low index means a short arm, and vice versa.

Name of race	males	females	both together
Australians (T)	....	....	approx. 68
Australians (M)	68.7		
Negroes (M)	68.3	68.1	68.2
Negroes (T)	....	....	69.0
Andamanese (T)	....	....	69.0
Fuegians (M	69.4	70.8	70.1*
Europeans (Alsace) (M)	70.4	69.3	69.7

* The total length in millimeters of Fuegian limbs (bones) averaged at 758 mm. for males, and 709 mm. for females, according to Martin. These were taken from a large number of individual bones.

4. *Humero-femoral index* $\frac{\text{length of humerus} \times 100}{\text{length of femur}}$

This comparison gives the relative length of the humerus, when compared with the thigh. Martin gives the following values:–

Name of race	males	females	both sexes
Fuegians	69.8	72.9	71.3
Negroes	72.4	71.8	72.2
Europeans, Alsace	69.0	68.8	68.9

The indices that follow have been seldom used, and some of them may even have never been practically employed. They are placed here mainly to show some of the many possible combinations, since any one of these or similar ones may at any time be found to clearly present a certain new relationship. To guard against an excessive employment of indices, one should always have in mind exactly what real relationship a given index is intended to show, and never use one (in published writings) merely for the reason that it has never been employed before.

5. *Tibio-radial index* $\frac{\text{length of radius} \times 100}{\text{length of tibia}}$

6. *Humero-skelic index* $\frac{\text{length of humerus} \times 100}{\text{lengths of femur} + \text{tibia}}$

7. *Radio-skelic index* $\frac{\text{length of radius} \times 100}{\text{lengths of femur} + \text{tibia}}$

8. *Femero-brachial index* $\frac{\text{length of femur} \times 100}{\text{lengths of humerus} + \text{radius}}$

9. *Tibio-brachial index* $\frac{\text{length of tibia} \times 100}{\text{lengths of humerus} + \text{radius}}$

Relation of the Lengths of Limb-bones to The Total Stature of the Same Individual, when Living

The relationship of the lengths of the long bones to the stature of the individual, if possible to establish, would be a priori of immense importance in the constantly recurring problem of estimating the height, during life, of individuals known only be excavated bones. This is a ways the first question of people in general, who happen to be present when excavations are going on, and it is a curious fact in popular psycho ogy that heights calculated by unprofessional people are always excessive, sometimes ridiculously so. It would seem of much practical utility, then, to ascertain through a series of measurements the usual ratios of the separate long bone lengths to the total height, thus obtaining a coefficient, by which a given long bone may be measured to get the expected, or usual, bodily stature.

With such a purpose in mind Rollet, in 1889, took the total height measures of a series of dead bodies, 24 males and 25 females, between the ages of 20 and 65, in order to eliminate both senile and infantile proportions, after which he had the bones prepared and available for measurement. His results he formulated as follows:

Male. Femur (greatest length) multiplied by 3.66 = Total height
Female. Femur (greatest length) multiplied by 3.71 = Total height
Male. Humerus (greatest length) multiplied by 5.6 = Total height
Female. Humerus (greatest length) multiplied by 5.22 = Total height

These figures were, however, reliable only for people of about the medium height, 1650 mm. also, owing to the well-known differences of proportions in different human races, these coefficients would apply with any certainty only to Frenchmen, or at best to members of the white race.

The necessity of a sliding scale of coefficients for different sizes of individuals was taken into account later of by Manouvrier (1892) who calculated a series of different coefficients for bones of different sizes. Thus, for male femora, instead of using as coefficient the single "3.66" of Rollet, he used for a femur of 422 mm, the coefficient 3.85, for one of 446 mm, a coefficient of 3.73, and for one of 475 mm. a coefficient of 3.61, and so on.* He finally represented a set of coefficients for lengths of every few millimeters for the six long limb bones in each sex, and worked out the resultant stature in each case, from which a desired stature may be easily obtained. His table is as follows:

* MANOUVRIER: Le détermination de la taille aprés les grands os des membres. Mem. de la Soc. d'Anthropol. de Paris. 1893.

MALES

Fibula mm.	Tibia mm.	Femur mm.	Humerus mm.	Radius mm.	Ulna mm.	Total height mm.
318	319	392	295	213	227	1.53.0
323	324	398	298	216	231	1.55.2
328	330	404	302	219	235	1.57.1
333	335	410	306	222	239	1.59.0
338	340	416	309	225	243	1.60.5
344	346	422	313	229	246	1.62.5
349	351	428	316	232	249	1.63.4
353	357	434	320	236	253	1.64.4
358	362	440	324	239	257	1.65.4
363	368	446	328	243	260	1.66.6
368	373	453	332	246	263	1.67.7
373	378	460	336	249	266	1.68.6
378	383	467	340	252	270	1.69.7
383	389	475	344	255	273	1.71.6
388	394	482	348	258	276	1.73.0
393	400	490	352	261	280	1.75.4
398	405	497	356	264	283	1.76.7
403	410	504	360	267	287	1.78.5
408	415	512	364	270	290	1.81.2
413	420	519	368	273	293	1.83.0

FEMALES

Fibula mm.	Tibia mm.	Femur mm.	Humerus mm	Radius mm.	Ulna mm.	Total height mm.
283	284	363	263	193	203	1.40.0
288	289	368	266	195	206	1.42.0
293	294	373	270	197	209	1.44.0
298	299	378	273	199	212	1.45.5
303	304	383	276	201	215	
307	309	388	279	203	217	1.48.8
311	314	393	282	205	219	1.49.7
316	319	398	285	207	222	1.51.3
320	324	403	289	209	225	1.52.8
325	329	408	292	211	228	1.54.3
330	334	415	297	214	231	1.55.6
336	340	422	302	218	235	1.56.8
341	346	429	307	222	239	1.58.2
346	352	436	313	226	243	1.59.5
351	358	443	318	230	247	1.61.2
356	364	450	324	234	251	1.63.0
361	370	457	329	238	254	1.65.0
366	376	464	334	242	258	1.67.0

To use this Table the following rules are to be observed:

1. Determine the sex of the skeleton, if possible.

2. Take the length measurements of the six long bones given in the Table, or of as many of them as are in good condition. The *femur* is

measured "in the oblique position", i.e., physiological length; the *tibia* uses the medial condyle at the proximal end, but includes the entire malleolus distally, a departure from the rule laid down above; *the other bones* are used in greatest length.

3. If the bones are dry, and deprived of cartilage, add 2 mm. to the length measurement of each bone.

4. Find the nearest length for each bone separately, and set down the total stature expected. Lengths that fall in between those given will furnish their total stature through a simple calculation.

5. The series of total statures thus obtained should be averaged up in the usual way, by adding all together and dividing by the number of bones used. The resulting average is that of the cadaveral height.

6. The living height is considered to be 20 mm., less than the cadaveral height.

7. If you have the corresponding bones of the two sides, measure both, and use the average of the two for the measurement. If you possess the radius and tibia, the ulna and fibula need not be measured.

Although the values of this Table have been deduced from French bodies, and may not be wholly applicable beyond the confines of these and related peoples, still the work of Rahon* who applied them to a very large number of ancient men, in part absolutely prehistoric, possesses considerable interest. Some of his results follow:

	mm
Neandertal skeleton	1613
Spy skeletons	1590
Skeleton, La Madelaine	1665
Old man of Cro Magnon	1716
Mentone skeleton,	1732
Dolmen of "Cave-aux Fées"	males, 1600; females, 1470
Dolmen of "Bray-sur Seine	males, 1600; females, 1492
Merovingian Period, one skeleton of of each sex	males, 1771; females, 1579
Burgundians, 5th. Century	males, 1646; females, 1518
Carolingian Period	males, 1674; females, 1585

In all these the height given is that for the living. It is to be noted that the two first are now accredited to a distinct species, making their inclusion within this table quite inapplicable. The rest seem fairly reliable.

* Rahon, J.; La taille d'aprés les ossements préhistoriques. *Rev. Ec. Anthropol.* T. 2, p. 234 +. 1892.

Recherches sur les ossements humains anciens et prehistoriques en vue de la reconstitution de la taille. Mem. Soc. Anthropol. Paris, Series 2. T. 4, pp. 403 + 1893.

PART II

Somatometry; the Measurement of the Body

LANDMARKS

[The list here given is taken from Martin (Lehrbuch, 1914, pp. 120–131) but those of the head and face are given first, and the arrangement is alphabetical instead of topographical. The abbreviations are the same, and as they do not repeat any of those in use upon the skeleton, save in those cases where the two correspond, it is hoped that they will come into common use, much as in the case of the abbreviations of the elements in Chemistry].

(*a*) *Landmarks upon the head and face.*

alare (al)	The most external point on the wing of the nose.
bregma (b)	*
cheilion (ch).	Outer corner of the mouth; lateral terminus of the oral slit.
crinion (see trichion)	
ectocanthion (ex)	Outer corner of the palpebral opening.
endocanthion (en)	Inner corner of the palpebral opening, medial to the caruncula lacrimalis.
euryon (eu)	*
frontotemporale (ft)	*
glabella (g)	*
gnathion (gn)	*
gonion (go)	*
inion (i)	*(here taken as the occipital protuberance).
labrale inferius (li)	The median point in the lower boundary of the mucous surface of the lower lip.
labrale superius (ls)	The median point of a line drawn across the boundary of the mucous surface of the upper lip, tangent to the curves.
mastoidale (ms)	*
mesosternale (mst)	The point in the sternal median line crossed by the transverse line connecting the middle of the two 4th costal cartilages, at the insertion into the sternum. The determination of this cartilage is facilitated by first locating the 2d, which noticeably projects a little above the others.

* Points followed by an * are the same as those of like name upon the bony surface of the skull, save that here the point designated is upon the external surface of the skin, exactly above the one on the skull, and differs from this latter by the thickness of the soft parts. When used as the termini of lines parallel to the surface, the measuements of both skull and face are the same, when the thickness of the soft parts is included in the line measured, the two measurements differ by this amount. Thus, compare the least frontal breadth, where the measurements of skull and face are the same, with the greatest head breadth, where the breadth in the living includes the soft parts upon each end of the line, and is larger by so much than in the skull.

metopion (m)	The median point of the line connecting the two frontal eminences.
nasion (n)	*
ophryon (on)	Median point of the line drawn tangent to the upper border of the eyebrows.
opisthocranion (op)	*
orbitale (or)	*
otobasion inferius (obi)	Point where the ear attaches to the side of the head, above.
otobasion superius (obs)	Point where the ear attaches to the side of the head, below.
postaurale (pa)	The most posterior point in the free margin of the ear.
preaurale (pra)	The point in the line connecting the two otobasia, and crossing the isthmus of attachment of the ear to the head, which is directly opposite the postaurale. This line is at right angles to the ear length line.
pronasale (prn)	The point of the nose.
prosthion (pr)	*Owing to the gum this point lies about 1 mm. lower than on the bare skull.
stomion (sto)	Median point of the oral slit, when mouth is closed naturally.
subaurale (sba)	The lowest point in the free margin of the ear. This is also the lowest point of the lobe.
subnasale (sn)	Point of the angle between the septum and the surface of the upper lip.
superaurale (sa)	The highest point in the free margin of the ear.
tragion (t)	The notch just above the tragus of the ear.
trichion (tr)	The median point in the line of the hair. To be used only when the area covered by the hair is normal; not to be used when the hair has begun to retreat in incipient baldness.
tuberculare (tu)	Darwin's point on the ear.
vertex (v)	Highest point of the head, when standing erect, or sitting as straight as possible.
zygion (zy)	*

(*b*) *Landmarks upon the trunk and limbs*

acromion (a)	The most lateral point of the acromion process, felt through the skin; found by tracing along the spine of the scapula, with index and middle fingers, or by following the shaft of the clavicle, or by laying the middle finger across the shoulder at the top, and gradually down over the side until it drops over the edge of the bone. This is a difficult point to learn to find, and should be practiced in connection with an articulated skeleton. One should first become familiar with all the superficial parts of scapula, clavicle and proximal end of humerus, and learn to locate and recognize them in the living by palpation, in the various positions assumed.
acropodion (ap)	The most forward projecting point of the foot whether, upon the first or second toe.
cervicale (c)	Free end of the spine of the seventh cervical vertebra; the *vertebra prominens*.

dactylion (da)	The distal point of a finger, designated as da I; da II; etc. When not specified, the one referred to is the point of the middle finger, *da* III, which is used in the series o distances from the floor. As thus used the arm hangs at the side in the most natural position.
ilioeristale (ic)	The most lateral point of the iliac crest; feel from below upwards with the fingers laid flat and horizontal (when the subject is standing), and parallel to the crest. The point sought is found where the surface of the bone passes over from the side to the top of the crest.
iliospinale anterius (is)	This is the anterior ventral spine of the crest of the ilium (old terminology; *anterior superior spine*) and is best found by placing the finger along the crest and feeling for it with the thumb.
iliospinale posterius (is.p)	This is the anterior dorsal spine (*posterior superior*) at the dorsal end of the crest.
labiomentale (lab.m)	Median point in the transverse groove in the chin at the point where the lower lip is attached, the sulcus labiomentalis. Find about as in the previous case. It is usually characterized upon the surface by the presence of a little dimple.
lumbale (lu)	The point of the spinous process of the fifth lumbar vertebra. This is difficult to locate and some anthropometrists do not use it because of this. Others recommend counting (and perhaps marking all the spines from the seventh cervical down, with the body bowed forwards. The lumbale can be marked when in this bowed position, and the point will then be present after the body is erect again.
mesosternale (mst)	The median point, on the sternum, of the line which connects the sterno-costal articulation of the two 4th ribs. The cartilages are to be counted by running the finger down the sides of the sternum, where they are superficial. Corresponding to the break between the manubrium and the mesoternum, where the 2nd costal cartilages are inserted, these cartilages project forwards a little, projecting beyond their neighbors. The second pair below this is the one sought.
metacarpale laterale (ml)	The most projecting point on the free outer margin of the hand, at the level of the basal joint (*metacarpophalangeal articulation*) of the little finger.
metacarpale mediale (mm)	The most projecting point on the free inner margin of the hand, at the level of the basal joint (*metacarpophalangeal articulation*) of the index.
metatarsale laterale (mt.l)	The most laterally projecting point of the metatarsophalangeal articulation of the little toe.
metatarsale mediale (mt.m)	The most medially projecting point of the metatarsophalangeal articulation of the great toe (*hallux*).
omphalion (om)	Middle point of the umbilicus; an unstable point.
phalangion (ph)	The most proximal point of the basal phalanx of a finger; designated as I, II, III, etc.
pternion (pte)	The most posterior point of the heel, when the foot is sustaining the weight of the body

radiale (r)	The plane of the top of the capitellum of the radius. In the hanging arm it is found in the bottom of the conspicuous groove or dimple of the elbow.
spherion (sph)	The lowest point of the inner malleolus.
stylion (sty)	The distal margin of the styloid process of the radius where it appears superficially upon the medial side of the wrist. In the hanging arm seize the wrist and palpate downwards over the surface of the process with the thumb. The exact end of the process may be felt with the thumb nail.
suprasternale (sst)	The middle of the suprasternal notch, in the upper margin of the sternum. This margin is covered simply by a thin layer of skin, and the point in question may be readily located with precision.
symphysion (sy)	Middle point in the upper border of the pubic arch, at the symphysis. This is usually at about the level of the upper border of the pubic hair, but as there is some variation in this it is not safe to rely wholly upon this when precision is wanted. Involuntary shrinking on the part of the subject, due to the tickling reactions, are obviated entirely by approaching the point from the side with the flat of the hand, and using the end of the finger only when the upper border of the pubic arch is reached. With intelligent subjects they may often be entrusted to find the proper point themselves, especially when an articulated skeleton stands beside the operator and subject, a condition which should never be neglected. This point is of vital importance in all studies of proportions, and ought always to be taken, and with as great precision as is practical.
thelion (th)	The middle point of the nipple. To be taken only in men, children, and in women with no perceptible tendency for the breasts to sag downwards.
tibiale (ti)	The medial separation between femur and tibia, at the medial glenoid margin of the latter; the point is difficult to find in persons with strongly developed panniculus adiposus in the knee region. To find this, place thumb and forefinger of the right hand upon the quadriceps tendon (*ligamentum patellae*), ask the subject to slightly flex the knee, and then slip the forefinger over to the side, and explore with the finger nail for the separation between the bones. This may be marked when found, for reference in other positions of the leg.
trochanterion (tro)	A point of some uncertainty and never vary precise. It is defined as the highest point upon the trochanter major, but in practice some use the most lateral point, thus making the bitrochanteric breadth a synonym of the greatest breadth across the thighs, with the heels together. Others reach the bone surface from behind, where the adhesion of the integument to the subcutaneous bone surface form a deep and noticeable hollow. To find the more precise point, as defined, the hand is placed nearly flat upon the region where the bone lies subcutaneous, and request the subject to move the leg

laterally, to bow the body forward, and to make other motions which concern either the femur or the adjacent parts. The shape of the process, and the position of its highest point may thus be located with a fair degree of accuracy.

MEASUREMENTS

(a) General Considerations; Position of Subject

In all measurements or other observations of the living subject it must first be emphasized that one is engaged in the study of the individual bodily variations of an animal species, and that, in order to obtain satisfactory results, the subjects, wherever possible, should be studied in the nude. When for various reasons this is not practicable, however, it will be found that the use of some slight covering does not materially interfere with the measurements, although it may be fatal to a number of other important observations which are conveniently made at the time of the mensuration. Thus it has been found that in a mixed class, or with observer and subject of opposite sex, the use of a simple bathing-suit allows the majority of the measurements to be taken with considerable accuracy, especially when the material of which the suit is constructed is of a sort which yields with the underlying surface, and does not restrain or confine in any way any part of the body.

As to the *position of the subject* when measured, opinions differ, the usual choice lying between two; (*a*) standing erect, and (*b*) placed in a horizontal position upon a measuring table. In the first the subject hands as erect as possible, with the heels together and with the arms and stands hanging at the sides; the "military position." If, when in this position, the exact heights above the floor of certain essential landmarks be taken, many essential measurements may be obtained through the subtraction of these numbers from one another, thus finding the differences between them. To be exact, however, both the numbers indicating heights, and the lengths obtained from them are really projections, and concern, not actual points, but the horizontal planes in which the points lie.

To illustrate; if, in a naturally hanging arm, with hand extended downward, the distance of the floor from the points *acromion*, *radiale*, *stylion*, and *dactylion* be accurately taken, the subtraction of the radiale height from that of the acromion, will give the height of the upper arm, that of the stylion height from the radial height gives the length of the forearm (*i.e.*, of the radius); and that of the dactylion height from that of the stylion will give the length of the hand. The total length of arm and hand is obtained by subtracting the dactylion height from that of the acromion, and so on It will be noticed, however, as these heights are each that of horizontal plane passing through the landmark in question hat the lengths obtained by subtraction are the actual perpendicular distances between the two planes considered; and that, in case a bone hangs in the body a little obliquely, its actual length will exceed by a little its projected length, or that obtained by the subtraction of heights. To give another example, take the distance in height between any lateral point and a median one, as, for instance, *thelion* and *omphalion.* The height of either of these, as taken, means the height of a horizontal plane through which the point in question passes, and the difference in height obtained by subtraction means the perpendicular distance between the two planes, that of thelion and that of the omphalion. In actually measuring the straight distance from one of these points to the other we are dealing with an oblique line, which has nothing necessarily to do with the horizontal plane of either point.

Aside from dealing with projections, which is the really scientific method of dealing with relative heights, the use of these projected heights has the decided advantage of saving much time, important alike to subject and operator. It is easily possible to run through the usual list of heights (about 25) within a very few minutes, after which many other measurements, such as the lengths of separate parts of the limbs or the projected distance between trunk landmarks, may be readily calculated in the study.

In the other types of measurement, such as breadths, or girths, the standing position of the subject is extremely convenient, with the possible exception of the few that concern that portion of the figure below the knee, where some stooping is required on the part of the operator, but this is quite inconsiderable, as there is but a small number of such data to be obtained.

For measuring the body in the horizontal position the only absolute essential is a horizontal table six feet or a little more in length, and two and a half feet in breadth, upon which the subject may be placed upon the back. To admit a little comfort a slight pillow is admissable, care being taken that it does not materially change the position of neck or head.

To these simple essentials many improvements may be added, for the comfort of either operator or subject, or both. For example, the board may be crossed by transverse lines in black painted and graded to serve as an anthropometer; or, by means of some simple staging, the metal rod of the regular anthropometer may be suspended horizontally above the subject, while one of the cross-bars, slipping back and forth upon the graded rod, marks the points desired with precision. Frassetto, the anthropologist of Bologna, one of the chief advocates of this position, has a table that swings upon a strong steel cross bar, which runs across the middle of the table. The subject takes his position when the table is set upright on the floor, with his feet standing upon the transversely placed board at the lower end, and with his back touching the table top. When this is done the table is swung slowly into the horizontal position by some such mechanisms as are used in the chairs of dentists and barbers, and the subject is ready to be measured.

Concerning the relative advantages of the two positions, they may be set forth as follows:

Erect position	Recumbent position
1. A rigidly erect position is hard to maintain; a fatigued subject frequently shrugs the shoulders and sways at the hips, thus constantly making differences of a centimeter or more in some of the longer measurements.	The ease with which a body lies on the back insures a much quieter and more motionless position than in a standing subject. This allows more accurate measurement.
2. [No counter argument].	Children, and even babies, may be measured in a recumbent position where an erect and motionless position is impossible.
3. [No counter argument].	The dead body may be measured in the recumbent position, and, allowing for a certain amount of relaxation, the data thus obtained may be directly compared with those from the living.
4. [No counter argument].	The bodies of apes and monkeys, as in the case of dead bodies, can be directly compared with data obtained from the living, when measured in the recumbent position, while, if the living are measured erect, no comparison is possible.
5. Primitive and superstitious people, who often object to any form of measurement, still often allow more or less of it, when allowed to stand erect. It would usually prove quite impossible to place them on their back for any form of measurement or other investigation, as this position would be felt by them to be a position of defencelessness or of actual dishonor.	[No counter argument].

As a purely academic question the arguments seem about equally balanced, with possibly a little more weight upon the side of the horizontal position, yet, the arguments against this position and in favor of a standing subject are so cogent from a practical standpoint (cf. argument 5), that at the International Congress of 1912 at Geneva the standing position was adopted as a part of the prescription. At this time the *general principles* adopted were the following:

(*a*) For measurements upon the living the *standing position* is adopted.

(*b*) The method of *projections* is adopted, save in cases where special mention is made of some other way.

(*c*) For paired measurements it is recommended that the work be done *upon the left side,* but that the measurements of both sides be taken in the cases of the acromial and trochanteric heights above the ground.

(*d*) Observers are requested to always carefully *indicate their methods* and their instrumentation.

(*e*) It is very strongly recommended to all persons wishing to do any anthropometric work not to be content with a theoretical study of the principles of mensuration, but *to learn them practically* in one of the different laboratories in which they are taught.*

A certain number of prescriptions for the measurement of the *living head* (some 19) was included in the prescription of 1906, at Monaco, which form the basis of all later proposals. Certain measurements of the trunk and limbs were decided upon during the session of 1912, at Geneva, and are equally fundamental. In the list which follows, and which includes, not only the measurements of the two original lists, but others that have received general approval since then, the former are marked by an asterisk. These lists, in their original form, may be found as follows:

I. Skulls and living heads, Monaco 1906.
   French; L'Anthropologie, T. 17, 1906, pp. 559–572; reported by Papillault.
   English; Journ. Roy. Anthrop. Inst. reported by Duckworth.

II. Trunk and limbs of the living, Geneva, 1912.
   French; L'Anthropologie, T. 23. 1912, pp. 623–627, reported by Rivet.
   Italian; Rivista di Antropologia, 1912, Vol. XXII Fasc. III. pp. 1–15 reported by Frassetto.
   German; Korrespondenzbl. der Deutschen Anthropol. Gesell. 1913, Jahrg. XLIV, No. 1. Publ. in Archiv für Anthropologie; reported by Schlaginhaufen.
   English; Journ. Roy. Anthrop. Inst. reported by Duckworth.

(*b*) Lists of Usual Measurements

A. ON THE HEAD

1. *Linear measurements.*

1. Maximum head length (g-op)
2. Glabella-inion length (g–i)
3. Maximum head-breadth (eu-eu)
4. Least frontal breadth (ft–ft)
5. Bizygomatic breadth (zy–zy)
6. Bigonial breadth (go-go)

* The italics are those of the present author; the translation is free, after the French version (*L'Anthropologie,* T. 23, 1912, pp. 623–627, by RIVET).

7. Biauricular breadth (t–t)
8. Bimastoid (ms–ms)
9. Biocular breadth (ex-ex)
10. Interocular breadth (en–en)
11. Interpupillary distance (with pupillometer)
12. Breadth of palpebral opening (Subtract No. 11 from No. 10)
13. Nasal breadth (al–al)
14. Oral breadth (ch–ch)
15. Auricular height (t–v); projection, *i.e.* difference of level between tragion and vertex; may be done either by anthropometer as in the case of the skull or by subtraction.
16. Height, vertex to subnasale (v–sn) by subtraction, or in projection with anthropometer.
17. Physiognomic facial length (tr–gn); only in individuals with normal extent of hair.
18. Morphological facial length (n–gn)
19. Physiognomic superior facial length (n–sto)
20. Morphological superior facial length (n–pr)
21. Nasal length, in ground plan (n–ns); used for nasal index with 13
22. Nasal length, along profile (n–prn)
23. Nasal height, projection from face (prn–sn)
24. Frontal height, physiognomic (tr–n); only in individuals with normal extent of hair.
25. Height of mucous lips (li–ls)
26. Height of entire upper lip, (sn–sto)
27. Height of entire lower lip (sto–slm)
28. Height of chin (sto–gn)
29. Physiognomic ear length (sa–sba)
30. Physiognomic ear breadth (pra–pa)
31. Morphological ear length, cf. ear of horse, sheep etc. (t–tu)
32. Morphological ear breath (obs–obi)

2. *Angles.*

33. Profile angle (line FH with line n–pr prolonged)
34. Camper's facial angle (line meat–sn with line on–sn)
35. Superior facial angle (line meat–pr with line meat–n)

3. *Girths.*

36. Horizontal circumference of the head. Put the "O" of the tape measure at the glabella with the left hand, lay tape with the right hand along the left side of the head over what appears to be the opisthocranion and thence around to point of beginning. Shift until correct, with the tape placed horizontally and drawn over the opisthocranion.

37. Sagittal arc; with the tape, from nasion, over top of head, to inion, in the median plane. This does not quite correspond to the like-

named measurement on the skull, as in the latter the posterior terminus of this arc is on the opisthion.

38. Transverse arc; from tragion to tragion, over the vertex.

B. ON THE TRUNK AND LIMBS.

1. *Height from floor (Projections)*

1. Ht. vertex (total stature)
2. Ht. tragus
3. Ht. gnathion (eyes looking straight ahead).
4. Ht. suprasternale
5. Ht. thelion (not taken in women with hanging breasts)
6. Ht. mesosternale
7. Ht. omphalion
8. Ht. symphysion
9. Ht. iliocristale
10. Ht. iliospinale
11. Ht. vertebrale
12. Ht. lumbale
13. Ht. acromion
14. Ht. radiale
15. Ht. stylion
16. Ht. dactylion
17. Ht. trochanterion
18. Ht. tibiale
19. Ht. spherion

2. *Sitting height; from plane of seat.*

[For these the subject should be seated upon a low, level table, where the foot of the anthropometer should also rest. If the feet be placed upon a rather high chair, thus lifting the dorsal muscles of the thigh from contact with the table, they cannot be used by the subject in lifting the body, while it rests directly upon the sciatic tubers (ischiadic tuberosities), here quite subcutaneous]

20. S. Ht. vertex (This gives the trunk length between vertex and the lowest point of the pelvic girdle).

21. S. Ht. tragus (This gives the trunk length from the first vertebra, as the tragus level is practically the same as that of the occipital condyles, or the plane tangent with the upper projections of the atlas. (The subject must look straight ahead, as in Measurement 3, and some others).

22. S. Ht. suprasternale (This gives the trunk height from the anterior end of the sternum, a point often used).

23. S. Ht. vertebrale.

24. S. Ht. iliocristale (This gives the height of the pelvic girdle).

3 *Arm-stretch.*

25. Arm stretch (The best way to get this is to place the subject against a wall, with arms extended horizontally, with shoulders and dorsal aspect of the arms in contact with the wall, and with the palms facing forwards. The extreme distance between the points of the two middle fingers when exerted to the utmost is the distance to be measured. It facilitates measurement if the wall be marked in centimeters along a horizontal area where the arms of the subject may be expected to come; also if one middle finger tip be placed in contact with a small board placed vertically upon the wall, the attention may be more completely directed to the position of the other.

In default of a wall the anthropometer may be held horizontally behind the subject, and the fingers used to push the rods apart).

4 *Diameters.*

26. Biacromial diameter (a-a).
27. Breadth of shoulders between the deltoids; widest place (secdary).
28. Bimammillary diameter (th-th).
29. Ilio cristal diameter; "cristal breadth" (ic-ic)
30. Iliospinal diameter; "spinal breadth" (is-is).
31. Bitrochanteric diameter; "trochanteric breadth" (tro-tro).
32. Dorso-ventral pelvic diameter (lu-sy).
33. Dorso-ventral diameter of thorax; plane I (at level of base of ensiform cartilage).
34. Transverse diameter of thorax; Plane I.
35. Dorso-ventral diameter of thorax; Plane II (level of mesosternale).
36. Transverse diameter of thorax; Plane II.

[The four above diameters of the thorax are to be taken with the chest midway between a full inspiration and an expiration.]

37. Bicondylar diameter at elbow (secondary).
38. Bistyloid diameter at wrist (secondary).
39. Bicondylar diameter at knee (secondary).
40. Bimalleolar diameter at ankle (secondary).

5 *Girths*

41. Girth of neck, across larynx.
42. Girth of thorax, Plane I; (quiet breathing, midway between inspiration and expiration).
43. Girth of thorax; Plane II; (quiet breathing. Lift arms to shoulder height, and place tape around chest, well up in the axillæ, at level of mesosternale; then let arms drop, while tape is held in place by the operator. Let subject continue quite breathing, and take the middle point shown by the tape between the extremes).
44. Girth at waist, least girth of body.
45. Girth of upper arm, greatest when relaxed.

46. Girth across contracted biceps.
47. Girth of forearm, greatest.
48. Girth of wrist, least.
49. Girth of thigh, greatest (in or about the gluteal fold).
50. Girth of thigh, middle.
51. Girth of thigh, least (just above knee).
52. Girth of calf
53. Girth of ankle, least.
54. Contour tracing of hand (traced with a split pencil, held vertically).
55. Length of hand (either by subtraction of No. 16 from No. 15, or by direct measurement between stylion and dactylion).
56. Breadth of hand (mm-ml).
57. Contour of foot (as in No. 54).
58. Length of foot (burdened by weight of body), (ap-pte). This is most conveniently taken with the osteometric board. The subject stands upon this, with the farthest forward point (acropodion) in contact with the fixed board which indicates O. The moveable board is then moved up to contact with the heel (pternion).
59. Breadth of foot (burdened by weight of body). (mt.m-mt.1).

C. Weight (*in Kilograms*).

60. Weight of body (without clothing).

As the weight without clothing is often inconvenient to obtain, the following data on the weight of clothing [Martin, p. 152] may be found useful. These data are taken from the dress of Central Europe, which should be about the same as found in the United States.

I. Total weight of clothing, without hat; averages.

man, in summer	3800 grams
man, in winter	4500 grams
woman, in summer	3000 grams
woman, in winter	4000 grams

II. Percentage of clothing in the total weight (clothed) of children.

boys; 3–6 years	6%
girls; 3–6 years	7%
boys; 7–14 years	8%
girls; 4–14 years	7%

III. Average weights of certain garments.

boy's shirt	100 grams
boy's shirt and stockings	300 grams
girl's chemise and petticoat	500 grams
shoes; children of six years	200 grams
half-shoes of older children	350 grams
boys boots	700 grams

Measurements Obtained By Calculation From Other Measurements

(1) Trunk length

It is very important to determine upon the best of the many possible trunk-lengths and use it exclusively and universally, since especially it is of great importance in all comparisons with the limbs, but unfortunately there are many possible trunk-lengths, and each may have certain advantages, such as greater availability, or a better value for comparison. The many possible limits to be set to this length, each one with some following, are the following:—

Upper limit	Lower limit
Tragus	Lumbale
Subnasale	Symphysion
Inion	Sciatic tuber
Cervicale	End of coccyx
Suprasternale	

For the upper limit the tragus and subnasale, in a standing figure with eyes forward are either of them in about the plane of the upper face of the atlas, and thus give the upper limit of the vertebral column. The inion is a bit higher, but is easy to locate (meaning here the occipital protuberance). The two others, cervicale and suprasternale, are used as the upper limit when the trunk alone is desired, counting off the cervical region, as is often done. In the case of the lower limit neither symphysion nor lumbale give the full value to the physiological trunk, since they omit the lower part of the pelvic girdle. This latter is, morphologically a part of the appendage, and thus shows certain arguments in favor of the omission. Viewed physiologically, however, the girdle is a part of the trunk, and thus should be included down to the plane of the sciatic tuber or the end of the coccyx. At present this view prevails, and the choice rests much in favor of the first. To use the plane of the sciatic tuber for the lower limit of the trunk it is simply necessary to seat the subject upon a table in the manner recommended above, with the feet supported rather high, so that no aid can be furnished from the dorsal muscles of hip or thigh, and then take the height from the table of any of the upper limits decided upon. Thus, selecting the suprasternale, as here recommended if the neck is not to be included, the height of this landmark in the seated subject is also the trunk-length. Should one wish to include the neck, use the tragus height.

(2) Arm length

Length of entire arm and hand	By direct measurement, from acromion to dactylion; arm either extended horizontally or hanging pendulous; hand in either case extended so far as possible.	By projection, by subtracting ht. of dactylion from ht. acromion.

Length of entire arm, without hand	Direct; between acromion and stylion, in extended arm.	By subtracting ht. stylion from ht. acromion.
Length of upper arm	Direct; between acromion and radiale.	By subtracting ht. radiale from ht. acromion.
Length of forearm	Direct; between radiale and stylion.	By subtracting ht, stylion from ht. radiale.
Length of hand	Direct; between stylion and dactylion, hand extended.	By suotracting ht. dactylion from ht. stylion.

Limb measurements are a little longer when taken direct than when calculated by subtraction (projection method). Thus the forearm, where the difference is the most marked, is about 6 mm. longer by the first method, but the upper arm is longer by only about .5 mm. The other results differ by about 3 mm.

(3) Leg length

In the leg there is no definite landmark to use as the proximal limit, as the pelvic girdle has a different physiological relation to the body from that of the shoulder girdle, and consequently there is no point on the former to serve the same purpose as the acromion. It is usual to consider the head of the femur as marking this limit, but here the difficulty is hat this feature lies too deeply for palpation, or even approximately locating it. One may use, however, its average relative distance from other landmarks, and by such means several of the following rules have been devised.

Total length of leg from head of femur to sole; subject standing	(*a*) Subtract 40 mm. from iliospinale, or (*b*) Add 35 mm. to symphysis.
Total length of leg without foot	Subtract ht. sphyrion from ht. iliospinale, and from this result subtract 9% of itself.
Length of thigh	(*a*) Subtract tibiale from iliospinale, and from this result subtract 7% of itself. This corresponds to the physiological length of the femur. (*b*) Take the direct measure between iliospinale and tibiale, and from this subtract 40 mm. (*c*) Subtract tibiale from symphysion and then add 10% of this result.
Length of lower leg	Subtract ht. sphyrion from ht, tibiale.

INDICES

(*a*) Indices referring to certain measurements as standards.

In comparing a number of measurements together it is sometimes convenient to refer them all to a certain definite standard, especially if this standard is itself one that is not very variable. For instance it would occur to everyone to use as such a standard, the total stature, to which other measurements, such as the lengths of arm or leg, trunk-length or thoracic depth, could be referred, and through which they could be compared with one another; the comparison would become unjust in the case of an individual with an abnormally long neck, yet, in the majority of cases, this standard would serve its purpose.

Two such standards are commonly used, and the sets of indices are the following:

$$\text{I. Index } a = \frac{\text{any bodily measurement} \times 100}{\text{total stature.}}$$

$$\text{II. Index } b = \frac{\text{any bodily measurement} \times 100}{\text{trunk length (sitting height of sst).}}$$

For this latter Martin uses the distance (projected) between height of suprasternale and the perineal height; but as this latter point is not advocated here, and is difficult to obtain, the distance sst—sciatic tubers is substituted.

(*b*) **Convenient indices which bring out comparisons which are frequently desired.**

$$\text{Brachial index } \frac{\text{length of forearm} \times 100}{\text{length of upper arm}}$$

$$\text{Forearm-hand index } \frac{\text{hand length} \times 100}{\text{length of forearm}}$$

$$\text{Hand index } \frac{\text{hand breadth} \times 100}{\text{hand length}}$$

$$\text{Tibio-femoral index } \frac{\text{length of lower leg} \times 100}{\text{length of thigh}}$$

$$\text{Lower leg-foot index } \frac{\text{length of foot} \times 100}{\text{length of lower leg}}$$

$$\text{Intermembral index I } \frac{\text{length of entire arm} \times 100}{\text{length of entire leg}}$$

$$\text{Intermembral index II } \frac{\text{length; upper arm + forearm} \times 100}{\text{length; thigh + lower leg}}$$

$$\text{Femoro-humeral index } \frac{\text{length of upper arm} \times 100}{\text{length of thigh}}$$

$$\text{Tibio-radial index } \frac{\text{length of forearm} \times 100}{\text{length of lower leg}}$$

$$\text{Upper arm girth index } \frac{\text{max. girth upper arm* } \times 100}{\text{length of upper arm}}$$

$$\text{Forearm girth index } \frac{\text{max. girth forearm} \times 100}{\text{length of forearm}}$$

$$\text{Arm proportion index } \frac{\text{max. girth forearm} \times 100}{\text{max. girth upper arm*}}$$

$$\text{Forearm proportion index } \frac{\text{min. girth forearm} \times 100}{\text{max. girth forearm}}$$

* with biceps muscle not contracted.

Thigh girth index $\frac{\text{max. girth of thigh} \times 100}{\text{length of thigh}}$

Lower leg girth index $\frac{\text{max. girth of lower leg} \times 100}{\text{length of lower leg}}$

Leg proportion index $\frac{\text{max. girth of lower leg} \times 100}{\text{max. girth of thigh}}$

Lower leg proportion index $\frac{\text{min. girth of lower leg} \times 100}{\text{max. girth of lower leg}}$

Mammilo-acromial index $\frac{\text{bimammilary diameter} \times 100}{\text{biacromial diameter}}$

Cristo-spinal index $\frac{\text{iliospinal diameter} \times 100}{\text{iliocristal diameter}}$

Acromio-cristal index $\frac{\text{iliocristal diameter} \times 100}{\text{biacromial diameter}}$

Body breadth index $\frac{\text{bitrochanteric diameter} \times 100}{\text{biacromal diameter}}$

Thoracic index I. $\frac{\text{transverse thoracic diameter I} \times 100}{\text{sagittal thoracic diameter I}}$

Thoracic index II. $\frac{\text{transverse thoracic diameter II} \times 100}{\text{sagittal thoracic diameter}}$

Skelic index [Manouvrier] $\frac{\text{leg length * } \times 100}{\text{trunk length}}$

hyperbrachyskelic	below 75
brachyskelic	75–80
subbrachyskelic	80–85
mesatiskelic (mesoskelic)	85–90
submakroskelic	90–95
makroskelic	95–100
hypermakroskelic	100

Constitutional index The maximum thoracic girth in centimeters + the total weight in kilograms is to be subtracted from the total stature in centimeters. Difference between these two numbers below

10	denotes a very strong constitution
11–15	denotes a very strong constitution
16–20	denotes a very good constitution
21–25	denotes a very fair constitution
26–30	denotes a very weak constitution
31–35	denotes a very weak constitution
above 36	denotes a very bad constitution

* To use the accompanying table of values it is of course necessary to use also the measurements of the author [Manouvrier]. His *leg length* is that obtained by subtracting the total sitting height, from the vertex to the table on which the subject is sitting, and his trunk length is the same as the total sitting height.

This index has little if any value in individuals, but, representing an average of many individuals of one race, it has significance concerning the race.

Weight index [index ponderalis of Livi] $\frac{\text{cube root of the weight} \times 100}{\text{total height}}$

APPENDIX A

MEASUREMENTS OF THE SKULLS OF 93 INDIANS FROM SOUTHERN NEW ENGLAND

MARIAN VERA KNIGHT, A. M. (SMITH)

From The Craniometry of the Southern New England Indians; Mem. Conn. Acad. Sci, July 1915 from the Anthropometrical Laboratory of Smith College.

TABLE, GIVING THE RANGE OF VARIATION AND THE MEAN FOR EACH MEASUREMENT TAKEN FOR EACH SEX, AS FAR AS AVAILABLE.

Designation of measurement	Males			Females		
	Ave.	Max.	Min.	Ave.	Max.	Min.
Maximum length (g-oe)	182.2	203.5*	169.0	175.5	188.0	158.0
Maximum breadth (eu-eu)	134.0	151.0	120.0	132.0	145.0	124.0
Glabella-inion length (g-i)	175.5	206.5*	161.0	164.4	178.0	150.0
Nasion-inion length (n-i)	171.0	200.5*	157.0	160.3	169.0	145.0
Frontal arc (arc n-b)	126.2	142.0	112.0	123.0	137.0	113.0
Parietal arc (arc b-l)	122.7	129.0	101.0	119.4	129.0	101.0
Occipital arc (arc l-o)	118.8	147.0	101.0	113.3	137.0	101.0
Frontal chord (n-b)	113.6	127.0	104.0	108.0	116.0	102.0
Parietal chord (b-l)	109.6	121.0	99.0	107.2	117.0	96.0
Occipital chord (l-o)	97.8	109.0	85.0	96.8	114.0	89.0
Total facial length (n-gn)	113.58	126.0	103.0	111.9	127.0	102.0
Superior facial length (n-pr)	69.2	76.0	59.0	67.3	76.0	57.0
Orbital height (right angles to mf-ek)	33.83	36.0	31.0	33.78	36.5	31.0
Nasal height (n-ns)	50.35	57.0	39.0	49.4	.....	.....
Chin height (id-gn)	34.1	39.0	31.0	32.5	38.0	28.0
Least frontal breadth (ft-ft)	93.2	108.0	82.0	90.0	99.0	82.0
Interfrontomalare temporale (fmt-fmt)	98.0	104.0	92.0	93.0	100.0	85.0
Interfrontomalare orbitale (fmo-fmo)	98.05	.....	.....	93.0	.....	.....
Interorbital breadth (la-la)	23.6	27.0	18.0	20.8	.....	.....
Bizygomaxillary breadth (zm-zm)	105.9	112.0	83.0	99.3	100.0	87.0
Bizygomatic breadth (zy-zy)	132.0	147.0	110.0	127.6	135.0	121.0
Biauricular breadth (au-au)	123.2	138.0	104.0	120.3	128.0	112.0
Orbital breadth (mf-ek)	42.52	47.0	39.0	41.56	43.0	36.0
Nasal breadth (right angles to n-ns)	25.77	31.0 =†	21.0 =	.....	.....	.....
Greatest frontal breadth	119.1	123.0	101.0	111.3	125.0	99.0
Horizontal circumference over glabella	518.1	555.0	495.0	497.0	532.0	461.0
Horizontal circumference over ophyron	511.1	546.0	490.0	492.5	523.0	456.0
Transverse circumference	324.6	370.0	301.0	312.6	337.0	270.0
Basal facial length (n-ba)	102.3	.....	.....	97.5	.....	.....
Cranial height (ba-b)	136.1	......	......	133.2	.....	.....

*The maximum measurements for males are much increased, especially in length measures of the cranium by including a single skull of huge proportions which come from a cemetery in Warren, R. I. If this had not been included, the three measures here indicated would have been, respectively, 198, 190, and 194.

† (=) Measurements thus given are without separation of the two sexes.

TABLE, GIVING THE RANGE OF VARIATION AND THE MEAN FOR EACH MEASUREMENT TAKEN FOR EACH SEX, AS FAR AS AVAILABLE.—*Continued.*

Designation of measurement	Males			Females		
	Ave.	Max.	Min.	Ave.	Max.	Min.
Basion-gnathion length (ba-gn)	114.1	.....	.....	110.5	.....	.....
Basion-opisthion (ba-o)	36.0	42.0	32.0	36.5	40.0	32.0
Breadth; occip. for (at right angles to ba-o)	30.7	35.0	22.0	30.76	33.0	22.0
Total sagittal arc (arc n-o)	368.7	398.0	336.0	357.0	383.0	330.0
Bimastoid breadth (ms-ms)	105.5	124.0	90.0	99.4	106.0	88.0
Maxillo-alveolar length	53.36	60.0	46.0	51.8	57.0	42.0
Maxillo-alveolar breadth	61.39	72.0	53.0	69.62	67.0	44.0
Palatal length	46.11	51.0	43.0	45.5	52.0	37.0
Palatal breadth	36.5	45.0	32.0	38.0	45.0	30.0
Auricular height	115.4	129.0	92.0	113.5	124.0	109.0
Condylar breadth	115.5	138.0	84.0	113.2	124.0	102.0
Bigonial breadth (go-go)	93.5	116.0	80.0	98.0	104.0	87.0
Length of ramus	58.7	74.0	51.0	55.0	66.0	44.0
Least breadth of ramus	35.5	41.0	29.0	33.8	39.0	28.0
Length-breadth	73.63	81.5	63.4	75.43	84.4	67.0
Length-height	74.73	81.67	64.36	75.90	84.12	65.57
Breadth-height	101.49	.....	.....	100.76	.....	.....
Length-auric. height	63.19	.....	......	65.14	....	.....
Transverse frontal	78.15	89.91	73.17	81.08	87.88	76.0
Transverse fronto-parietal	69.40	78.26 =	60.54 =	68.18	.....	.....
Sagittal fronto-par (arcs)	97.62	.....	......	96.75	.....	.....
Sagittal frontal; arc to chord	90.48	....	....	88.62	.....	.....
Sagittal parietal; arc to chord	89.43	....	....	89.92	.....	....
Sagittal occipital; arc to chord	82.35	....	....	85.84	......	.....
Total facial	84.33	....	....	87.84	.....	.....
Superior facial	52.27	....	....	52.34	.....	.....
Nasal	52.0	66.0 =	39.0 =	51.02	.....	.....
Orbital	80.95	92.0 =	74.0 =	80.49	.....	.....
Interorbital	23.47	....	....	24.70	.....	.....
Maxillo-alveolar	115.09	....	....	134.62	.....	.....
Palatal	78.26	107.14 =	65.31	84.44	.....	....
Cranio-facial; bizygomatic breadth by cranial breadth	98.51	109.2 =	85.71 =	96.97	.....	.....
Fronto-biorbital	94.90	....	....	96.77	.....	.....
Fronto-malar; least frontal breadth by bizygomatic	70.45	76.23 =	64.49 =	70.31	......	.....
Malar-mandibular; bigonial to bizygomatic breadths	70.45	....	....	76.56	.....	.....
Fronto-parietal (chords)	95.61	111.0 =	80.0 =	98.17	.....	.....

APPENDIX B

Bodily Measurements of 100 Smith College Students (Female) Taken by Margaret Washington, A. M. (Smith)

No.	Ancestry	Age	Total Height	Arm-stretch	Ht. Tragus	Ht. Vert. prom.
1	Dutch, Ger.	20	1738	1760	1599	1504
2	Welch, Norm.	23	1654	1683	1533	1420
3	Eng.	18	1655	1662	1513	1404
4	Jewish (Russ.)	21	1510	1540	1393	1289
5	Eng., Ir.	23	1543	1551	1400	1302
6	Eng.	20	1667	1688	1539	1431
7	Eng.	21	1636	1677	1515	1426
8	Eng.	21	1635	1621	1502	1382
9	Dutch, Scot.	21	1589	1584	1463	1339
10	Scot., Ir.	20	1694	1743	1551	1430
11	Eng.	18	1614	1663	1489	1383
12	Eng.	19	1747	1764	1606	1486
13	Scot., Ir.	21	1757	1745	1625	1502
14	Eng., Ir.	20	1662	1659	1538	1429
15	Ger., Fr.	19	1631	1668	1520	1400
16	Eng., Dutch	24	1564	1560	1440	1310
17	Eng.	22	1674	1672	1521	1407
18	Eng.	20	1698	1760	1554	1450
19	Eng.	18	1525	1509	1405	1286
20	Eng., Ir.	21	1555	1600	1422	1315
21	Scot., Ir.	22	1647	1680	1502	1386
22	Eng., Dutch	17	1662	1715	1540	1412
23	Ir., Dutch	23	1649	1620	1519	1402
24	Eng.	21	1637	1614	1513	1400
25	Eng.	20	1593	1569	1473	1367
26	Eng.	21	1695	1729	1574	1452
27	Eng., Scot.	19	1720	1743	1593	1469
28	Eng., Dutch	20	1627	1615	1499	1394
29	Scot., Ir., Ger.	19	1556	1577	1432	1321
30	Eng.	20	1642	1651	1509	1390
31	Scot., Dutch	21	1504	1509	1396	1274
32	Ir.	21	1684	1755	1552	1456
33	Eng.	21	1654	1687	1524	1422
34	Eng.	18	1630	1563	1505	1379
35	Eng.	20	1556	1552	1424	1323

No.	Ancestry	Age	Total Height	Arm-stretch	Ht. Tragus	Ht. Vert. prom.
36	Eng., Fr.	22	1562	1623	1445	1322
37	Eng.	22	1668	1624	1538	1436
38	Ger.	19	1598	1609	1476	1386
39	Eng., Scot.	20	1624	1553	1483	1380
40	Eng.	22	1606	1655	1459	1374
41	Eng.	20	1609	1685	1509	1386
42	Scot., Ir.	21	1714	1727	1580	1454
43	Eng., Scot., Ir.	21	1610	1597	1478	1380
44	Eng., Scot., Ir.	18	1657	1708	1523	1404
45	Ger.	20	1600	1605	1476	1361
46	Eng.	20	1651	1630	1512	1417
47	Ger., Ital.	20	1571	1588	1446	1347
48	Eng.	21	1696	1655	1571	1460
49	Eng., Soct.	20	1696	1700	1552	1461
50	Jewish (Ger., Rus.)	19	1621	1650	1480	1400
51	Eng.	21	1590	1563	1462	1365
52	Eng.	21	1620	1641	1495	1390
53	Eng.	20	1688	1664	1548	1430
54	Eng.	20	1634	1599	1523	1405
55	Eng.	24	1708	1792	1587	1464
56	Eng.	24	1648	1676	1510	1384
57	Eng.	19	1759	1728	1627	1515
58	Jewish (Rus.)	20	1545	1540	1423	1328
59	Ger., Fr.	21	1697	1644	1568	1453
60	Eng.	23	1636	1676	1511	1409
61	Eng.	22	1574	1568	1443	1342
62	Eng.	21	1680	1700	1555	1433
63	Scot., Ir.	21	1601	1581	1492	1371
64	Ger.	18	1669	1621	1521	1431
65	Ger.	18	1668	1631	1522	1433
66	Eng.	19	1594	1653	1479	1376
67	Eng.	21	1645	1730	1532	1400
68	Eng., Scot.	18	1609	1658	1470	1373
69	Eng., Fr., Ger.	19	1679	1673	1540	1430
70	Eng.	19	1685	1673	1558	1441
71	Eng., Ger.	20	1597	1542	1470	1372
72	Eng., Dutch	18	1636	1655	1495	1398
73	Eng., Ger.	20	1684	1640	1568	1450
74	Eng., Scot.	20	1650	1610	1523	1405
75	Eng.	19	1638	1710	1518	1414

No.	Ancestry	Age	Total Height	Arm-stretch	Ht. Tragus	Ht. Vert. prom.
76	Eng.	20	1663	1670	1532	1413
77	Eng., Fr.	22	1563	1564	1455	1350
78	Scot., Ir.	21	1548	1593	1435	1323
79	Eng.	18	1674	1625	1555	1432
80	Eng.	17	1696	1765	1568	1444
81	Eng., Scot., Fr.	21	1681	1702	1553	1451
82	Eng.	18	1640	1611	1513	1428
83	Eng.	20	1609	1570	1480	1363
84	Eng.	18	1667	1660	1534	1400
85	Eng., Ir., Welch.	20	1627	1681	1500	1395
86	Eng., Scot.	20	1697	1725	1562	1446
87	Irish	20	1696	1673	1537	1456
88	German	21	1611	1650	1477	1392
89	Eng.	25	1603	1624	1495	1373
90	Eng.	27	1641	1634	1517	1405
91	Eng.	21	1661	1605	1522	1432
92	Eng.	20	1551	1615	1439	1341
93	Scot., Ger.	19	1590	1622	1456	1345
94	Eng., Ger.	21	1674	1725	1534	1424
95	Eng., Scot.	19	1546	1560	1440	1307
96	Eng., Ger.	21	1562	1583	1446	1340
97	German	23	1584	1644	1465	1357
98	Eng., Dutch	20	1631	1595	1500	1402
99	Eng., Scot	20	1642	1694	1522	1400
100	Eng.	21	1612	1630	1485	1384

No.	Ht. Incis.	Ht. Acrom.	Ht. Nipple	Ht. Umbil.	Ht. Sp-il.	Ht. Troch.	Ht. S-pub.	Ht. Olecr.	Ht. St-rad.
1	1421	1421	1268	1064	1005	910	899	1100	847
2	1366	1357	1233	990	961	897	875	1062	794
3	1356	1325	1205	1001	923	920	860	1029	790
4	1232	1205	....	899	831	773	767	937	717
5	1247	1242	1111	919	857	806	790	957	729
6	1375	1362	1237	1022	946	874	847	1049	800
7	1349	1344	1189	995	939	863	832	1036	799
8	1326	1315	....	983	940	845	838	1012	785
9	1291	1295	1169	955	919	841	808	995	763
10	1379	1369	1246	1010	943	881	870	1061	757
11	1329	1316	1196	997	934	877	870	998	757
12	1450	1412	1276	1042	1008	939	913	1119	839
13	1426	1425	1223	1032	999	899	883	1126	837
14	1360	1365	....	1031	970	892	877	1106	825
15	1348	1351	....	970	917	843	819	1056	794
16	1283	1281	1137	918	852	872	775	993	762
17	1368	1361	1204	998	944	858	832	1056	800
18	1400	1385	1268	1050	996	947	920	1096	825
19	1232	1226	1102	898	837	782	756	948	725
20	1257	1264	1125	947	896	831	805	981	755
21	1340	1330	1192	966	919	832	823	1020	780
22	1354	1348	1219	1000	940	861	850	1056	790
23	1335	1327	1200	977	926	821	805	1029	787
24	1330	1325	1218	946	919	848	809	1031	790
25	1313	1282	1169	928	889	849	827	1005	782
26	1394	1354	....	1033	1003	919	907	1077	829
27	1410	1406	....	1010	991	908	872	1076	829
28	1332	1323	1191	991	912	854	821	1044	809
29	1267	1251	1144	920	889	807	748	955	744
30	1339	1341	1187	988	955	841	821	1057	790
31	1213	1207	1064	880	811	763	737	924	693
32	1401	1376	....	1048	951	907	886	1081	796
33	1365	1353	1227	1005	956	892	851	1039	783
34	1333	1301	1186	956	880	808	777	1011	781
35	1274	1247	....	921	884	829	804	980	737
36	1281	1253	1139	925	898	822	799	975	743
37	1372	1346	1235	995	921	855	822	1066	833
38	1306	1309	1165	942	902	813	769	1012	775
39	1333	1331	1196	963	903	840	809	1010	810
40	1328	1301	1189	957	909	845	825	1007	771

No.	Ht. Incis.	Ht. Acrom.	Ht. Nipple	Ht. Umbil.	Ht. Sp-il.	Ht. Troch.	Ht. S-pub.	Ht. Olecr.	Ht. St-rad.
41	1322	1290	1199	987	942	869	846	1019	759
42	1392	1363	....	1009	972	907	880	1091	832
43	1316	1300	1167	957	919	828	808	1033	808
44	1363	1338	1226	1039	937	887	875	1028	768
45	1306	1282	....	924	883	814	793	1061	778
46	1364	1330	....	992	926	835	808	1051	812
47	1281	1260	1152	927	860	808	774	998	756
48	1405	1385	1236	1023	988	910	881	1091	825
49	1391	1370	....	999	964	883	862	1093	843
50	1324	1310	....	980	936	890	877	1023	789
51	1307	1290	1162	943	892	842	790	1017	784
52	1313	1319	....	1015	927	872	838	1020	785
53	1372	1371	1246	1029	995	893	875	1080	836
54	1355	1321	1235	1004	926	860	841	1066	809
55	1411	1387	1270	1042	992	919	904	1063	809
56	1360	1341	....	923	832	832	824	1074	798
57	1436	1414	1280	1080	1013	980	897	1104	857
58	1268	1230	1137	907	859	806	773	977	755
59	1394	1369	1233	998	924	885	843	1088	837
60	1349	1324	....	1004	955	895	868	1039	777
61	1300	1290	1181	919	870	827	799	1026	800
62	1400	1362	1256	1010	953	881	856	1041	802
63	1325	1302	1189	968	925	885	846	1043	800
64	1360	1361	1233	1020	964	891	885	1080	838
65	1361	1349	1248	1030	966	911	879	1055	822
66	1306	1294	1170	964	914	875	836	1002	749
67	1360	1348	1242	1007	934	878	835	1045	803
68	1310	1292	1173	976	916	864	816	1012	773
69	1371	1355	1224	1024	970	907	857	1061	820
70	1402	1370	....	1000	964	924	894	1115	831
71	1302	1282	....	960	890	852	800	1014	789
72	1315	1310	....	997	959	884	858	1039	788
73	1393	1353	1222	1009	931	868	847	1078	834
74	1354	1316	....	961	899	849	820	1050	799
75	1342	1326	1222	973	948	895	855	1062	807
76	1361	1336	1236	1026	969	905	889	1042	798
77	1284	1258	....	906	874	818	762	1006	769
78	1268	1242	....	928	874	826	768	971	755
79	1360	1335	1235	1000	909	884	834	1081	844
80	1387	1375	1243	1044	980	950	942	1062	815

No.	Ht. Incis.	Ht. Acrom.	Ht. Nipple	Ht. Umbil.	Ht. Sp-il.	Ht. Troch.	Ht. S-pub.	Ht. Olecr.	Ht. St-rad.
81	1371	1347	1211	1000	965	923	934	1047	820
82	1350	1339	1192	1020	938	890	840	1068	828
83	1310	1290	1191	985	920	869	817	1015	777
84	1354	1340	1213	983	915	865	821	1041	814
85	1326	1316	....	965	910	852	813	1027	790
86	1374	1333	1206	1046	990	893	865	1052	810
87	1387	1337	....	1020	957	902	876	1090	830
88	1310	1300	1175	969	910	861	814	1037	780
89	1319	1301	1210	974	912	860	855	1019	792
90	1342	1310	1199	957	900	845	850	1050	825
91	1366	1361	....	996	940	858	832	1008	828
92	1274	1268	1160	945	900	852	932	973	748
93	1295	1269	1143	931	900	850	830	1004	746
94	1361	1337	1207	1015	943	893	857	1048	807
95	1247	1238	1111	950	865	814	770	977	733
96	1272	1272	....	933	860	842	789	1005	760
97	1301	1298	....	947	898	835	820	1010	758
98	1336	1322	....	973	930	865	855	1021	790
99	1344	1300	....	1012	952	895	895	1020	762
100	1316	1310	....	979	909	875	844	1047	772

No.	Height			Breadth				Length, breadth		
	Ht. Dact.	Ht. Knee	Ht. Mall.	Biacr.	Crist.	Troch.	Mamm.	Foot	Spin.	Th-width
1	669	469	80	385	281	255	217	254		
2	638	405	81	370	289	265	184	250		
3	608	417	68	369	270	217	212	230		
4	565	372	72	345	270	251	193	223		
5	547	395	70	344	246	220	196	219		
6	647	403	63	329	281	229	201	248		
7	617	424	81	368	250	211	185	236		
8	619	382	75	363	250	211	185	236		
9	602	382	71	326	266	240	. . .	251		
10	577	410	68	382	285	243	195	252		
11	594	406	57	369	248	231	211	235		
12	649	461	85	372	313	249	216	267		
13	644	455	81	345	299	249	196	239		
14	653	456	79	354	225	258	. . .	242		
15	622	431	71	363	235	239	. . .	241		
16	606	412	65	322	210	209	177	207		
17	628	438	85	356	270	283	186	245		
18	621	462	86	385	294	280	211	252		
19	564	392	73	349	268	273	220	226		
20	593	389	82	376	263	261	185	230		
21	612	396	72	370	258	215	215	247		
22	611	405	71	391	305	250	184	250		
23	617	414	72	369	262	248	188	242		
24	623	431	69	355	295	232	184	237		
25	622	435	68	336	294	241	208	220		
26	616	449	87	345	270	227	. . .	241		
27	650	429	73	376	291	254	. . .	246		
28	636	415	72	352	264	236	203	230		
29	566	391	79	249	255	229	188	229		
30	608	389	74	353	244	215	183	239		
31	561	353	79	302	247	210	193	223		
32	623	433	83	365	290	239	. . .	240		
33	618	439	89	386	269	221	221	238		
34	591	408	83	355	257	228	208	237	215	241
35	583	387	86	337	278	221	. . .	228	235	235
36	565	375	83	324	267	227	198	230	260	230
37	634	444	95	335	207	229	204	259	252	230
38	603	409	72	342	255	230	170	227	232	228
39	637	413	89	321	257	239	183	230	252	222
40	591	419	86	354	284	249	203	240	269	239

No.	Height			Breadth				Length, breadth		
	Ht. Dact.	Ht. Knee	Ht. Mall.	Biacr.	Crist.	Troch.	Mamm.	Foot	Spin.	Th-width
41	572	391	87	358	255	264	185	252	250	228
42	663	438	89	362	291	258	...	259	252	266
43	625	374	79	335	262	238	215	248	235	246
44	594	420	88	372	242	247	194	243	219	255
45	598	380	85	373	289	307	...	237	255	280
46	630	431	74	357	299	275	...	241	259	248
47	561	367	77	340	242	223	197	230	258	230
48	669	401	85	366	269	249	185	244	245	244
49	643	420	91	359	297	247	...	262	270	251
50	600	409	73	344	267	218	...	240	253	242
51	621	391	71	327	269	247	193	222	251	237
52	598	398	85	355	271	235	...	233	257	257
53	647	439	86	346	251	225	162	226	259	242
54	613	396	75	337	269	234	204	237	261	224
55	618	433	87	364	295	258	195	261	255	254
56	632	385	75	362	301	280	...	241	287	270
57	681	432	89	369	300	265	207	253	280	266
58	589	352	66	328	249	209	181	232	241	227
59	668	410	81	349	269	221	195	239	260	231
60	605	385	80	345	278	249	...	238	252	260
61	625	397	72	344	256	237	189	240	250	224
62	634	410	92	381	260	237	187	273	227	230
63	627	410	85	320	280	223	165	245	270	235
64	639	442	80	337	254	205	195	251	256	236
65	621	445	80	340	255	205	190	254	250	232
66	579	405	85	335	265	233	215	255	235	244
67	602	423	84	345	254	230	187	236	255	234
68	608	401	72	370	270	220	190	252	252	270
69	634	430	92	362	258	225	196	251	247	251
70	634	428	89	369	280	242	...	231	263	243
71	629	405	67	344	267	232	...	221	260	222
72	589	404	85	329	254	219	...	237	240	252
73	652	409	79	360	288	225	191	236	260	248
74	611	401	78	375	290	235	...	252	276	260
75	614	412	94	351	285	245	204	251	245	255
76	609	429	70	330	283	212	187	235	240	220
77	610	384	76	341	278	228	...	219	250	255
78	580	402	70	341	268	209	...	227	245	233
79	672	414	82	362	278	239	190	243	280	250
80	616	460	66	350	274	240	190	242	265	255

No.	Height			Breadth				Length, breadth		
	Ht. Dact.	Ht. Knee	Ht. Mall.	Biacr.	Crist.	Troch.	Mamm.	Foot	Spin.	Th-width
81	640	420	92	344	274	211	200	244	268	280
82	660	426	80	355	270	245	220	243	258	248
83	627	398	76	340	282	205	205	231	272	220
84	627	400	73	344	269	219	186	241	275	220
85	591	398	70	341	263	240	...	245	248	240
86	605	425	81	380	290	220	223	254	278	241
87	656	405	70	340	271	221	...	249	258	238
88	564	407	85	347	295	222	170	239	280	235
89	624	412	68	357	272	209	250	236	249	243
90	635	417	75	341	280	230	175	238	262	225
91	663	439	69	350	295	260	...	242	280	250
92	567	407	76	345	289	218	181	228	280	230
93	602	431	86	310	275	216	215	228	255	222
94	603	414	67	370	286	227	201	257	268	241
95	562	390	75	339	254	219	160	227	250	225
96	585	400	90	335	281	250	...	262	247	227
97	592	390	76	341	284	229	...	239	279	235
98	622	422	66	347	279	243	...	241	270	234
99	585	423	85	365	262	218	...	247	262	255
100	603	420	70	341	275	250	...	239	270	238

No.	Th-depth	Sitting heights				Measurements of face and head				
		Sht.	Vprm.	Inst.	Acro.	Hlth.	Hbth.	Frbth.	Inorb.	Zybrth.
1	...	904	651	594	587	188	149	100	34	120
2	...	861	631	569	547	101	143	101	28	121
3	...	880	629	562	556	184	137	99	28	115
4	...	825	605	551	531	184	150	106	32	125
5	...	830	581	527	522	184	152	106	30	116
6	...	885	645	587	561	190	149	100	31	124
7	...	852	639	555	548	186	148	107	30	122
8	...	857	612	550	536	188	148	103	30	116
9	...	853	608	563	560	191	146	96	24	111
10	...	875	617	570	563	191	146	106	31	125
11	...	836	611	537	526	175	146	99	29	112
12	...	897	643	589	565	193	139	98	34	119
13	...	953	710	636	629	196	141	101	28	116
14	...	870	632	569	569	185	148	105	31	111
15	...	868	634	585	584	188	140	111	30	126
16	...	835	590	568	557	180	141	103	26	90
17	...	890	628	565	562	181	149	102	29	120
18	...	875	628	577	567	187	151	106	32	124
19	...	840	601	533	527	186	146	102	31	112
20	...	827	589	540	525	196	154	103	33	121
21	...	803	658	608	598	187	144	104	31	125
22	...	890	643	583	562	193	151	104	35	119
23	...	889	646	583	561	188	155	108	33	118
24	...	869	640	562	561	189	140	96	29	111
25	...	861	637	561	556	183	145	100	28	116
26	...	868	628	558	539	185	151	97	30	118
27	...	903	655	589	585	194	143	101	28	120
28	...	864	628	576	539	186	144	99	29	116
29	...	833	592	529	508	177	148	105	33	113
30	...	861	630	549	543	178	145	102	27	112
31	...	813	600	539	520	182	148	103	32	114
32	...	861	640	571	551	185	146	107	29	123
33	...	867	629	555	537	187	150	99	27	113
34	172	914	668	618	589	188	146	104	30	123
35	173	821	591	537	510	191	150	97	29	121
36	144	825	582	541	514	194	143	99	30	109
37	182	896	666	603	579	187	147	105	34	122
38	165	843	621	546	545	180	148	101	30	115
39	168	860	613	559	555	183	147	96	33	115
40	165	853	623	552	529	193	150	100	30	120

No.	Th-depth	Sitting heights				Measurements of face and head				
		Sht.	Vprm.	Inst.	Acro.	Hlth.	Hbth	Frbth.	Inorb.	Zybrth.
41	175	847	623	549	510	180	147	104	30	118
42	183	883	627	572	552	194	153	103	32	107
43	184	843	623	555	525	187	146	106	33	124
44	192	853	611	559	530	196	144	104	34	121
45	215	873	638	581	555	187	150	104	30	124
46	179	781	634	569	545	192	152	108	32	123
47	175	863	629	562	539	185	147	97	31	106
48	171	889	649	582	556	189	143	103	29	124
49	168	908	680	595	575	188	146	105	27	123
50	180	840	620	547	537	182	146	92	29	111
51	172	849	613	578	545	174	151	95	28	110
52	185	854	622	556	534	180	143	105	30	113
53	149	885	629	569	678	188	145	102	36	116
54	171	861	629	570	533	181	147	99	31	115
55	208	885	635	584	555	197	145	102	32	122
56	230	877	632	585	555	202	155	109	28	125
57	197	939	700	616	590	188	151	107	33	123
58	160	836	622	562	520	173	150	99	34	114
59	179	920	676	604	567	183	147	99	28	117
60	165	833	612	545	516	194	146	97	32	115
61	167	839	607	550	530	186	142	95	30	109
62	173	884	636	581	546	187	144	98	29	111
63	166	824	599	552	523	174	144	100	25	109
64	175	840	613	530	530	185	142	96	27	116
65	175	848	620	551	539	185	142	97	28	116
66	169	834	609	538	525	184	147	104	30	119
67	139	855	607	554	550	180	145	103	31	114
68	170	836	610	540	520	188	150	103	30	119
69	168	880	640	565	548	193	153	107	33	121
70	167	880	634	590	554	192	152	110	31	121
71	160	860	627	555	529	190	147	97	30	104
72	176	840	607	528	518	190	140	104	27	117
73	179	916	677	627	587	190	146	100	31	118
74	174	899	637	584	554	186	154	107	31	121
75	185	878	640	567	551	196	156	108	36	122
76	175	842	600	535	506	187	150	104	32	114
77	171	839	610	541	526	178	140	101	30	109
78	168	830	581	526	512	181	145	101	30	109
79	165	907	660	585	561	185	148	106	34	120
80	180	893	638	593	577	200	157	114	35	133

No.	Th-depth	Sitting heights				Measurements of head and face.				
		Sht.	Vprm.	Inst.	Acro.	Hlth.	Hbth.	Frbth.	Inorb.	Zybrth.
81	182	873	641	560	540	191	150	102	29	116
82	173	840	622	555	540	183	147	102	28	108
83	165	846	602	550	535	185	149	100	35	113
84	176	892	641	590	575	178	149	103	33	118
85	180	856	621	556	534	186	150	97	35	113
86	175	887	630	558	525	194	145	98	29	117
87	161	897	661	591	541	192	150	102	34	116
88	160	855	620	545	527	180	143	98	32	114
89	154	842	621	546	519	176	144	102	32	123
90	160	851	614	546	521	173	146	94	28	106
91	190	893	663	603	597	191	150	120	30	130
92	139	811	600	530	515	189	145	101	30	114
93	154	824	592	534	514	186	146	104	31	118
94	185	885	636	576	552	189	152	107	32	119
95	165	824	579	526	526	184	138	97	30	110
96	167	856	626	570	570	182	142	103	32	104
97	167	835	613	557	547	187	144	101	36	115
98	182	856	627	572	544	183	143	101	31	117
99	165	947	608	543	500	192	144	111	30	107
100	187	841	820	542	542	181	149	103	35	114

No.	Measurements of head and face								Color of		
	Brdth. mand.	Chin to hair	Chin to nas.	Nas-pros.	Lth. nose	Brdth. nose	Lth. ear	Brdth. ear	Eyes	Hair	Skin
1	94	174	111	62	48	32	64	32	11	10	7
2	106	163	98	62	44	28	59	31	5	4	6
3	96	173	110	73	53	31	62	34	13	7	7
4	104	164	108	71	50	35	58	27	7	5	8
5	97	175	111	69	52	33	56	30	12	8	3
6	102	189	119	76	54	31	60	29	14	8	3
7	99	169	110	67	52	33	58	27	6	10	7
8	96	172	116	73	53	29	59	28	4	5	8
9	99	174	111	69	49	30	56	35	14	8	9
10	102	172	108	69	49	31	60	30	3	5	9
11	94	176	110	69	49	31	56	31	15	9	9
12	98	174	119	72	51	32	55	33	15	8	3
13	101	172	113	72	55	33	63	30	4	7	9
14	90	172	107	67	42	30	58	29	13	9	7
15	109	175	110	72	46	33	62	30	14	12	9
16	86	173	108	71	48	26	61	28	16	8	2
17	90	180	110	70	50	30	56	26	13	5	9
18	108	190	120	72	52	34	60	30	15	11	10
19	98	180	115	72	52	33	57	25	7	5	11
20	106	183	119	73	48	31	64	30	16	22	9
21	96	174	108	68	50	34	55	25	12	5	9
22	106	181	115	67	48	32	56	29	15	9	2
23	99	180	115	71	52	32	59	28	6	5	7
24	94	171	110	69	51	28	58	28	7	8	3
25	99	169	111	72	56	33	58	31	4	5	3
26	99	189	132	82	58	30	53	28	8	5	7
27	101	185	123	78	58	33	64	33	12	7	3
28	98	175	117	72	53	28	59	30	6	7	11
29	95	166	108	69	55	34	52	30	7	8	3
30	93	196	124	79	55	25	60	29	5	7	10
31	97	182	118	72	58	30	56	30	12	13	3
32	108	165	117	70	53	31	64	31	7	4	10
33	97	169	113	75	58	31	54	31	15	7	7
34	103	168	113	75	53	38	59	32	3	5	11
35	97	175	112	75	56	37	57	31	6	5	10
36	105	180	117	72	53	29	56	32	11	12	3
37	96	163	109	72	56	31	54	29	7	8	14
38	89	189	118	76	59	29	60	29	7	8	7
39	98	169	109	71	54	33	55	27	12	8	3
40	103	185	122	75	57	36	60	30	8	9	8

No.	Measurements of head and face								Color of		
	Brdth. mand.	Chin to hair	Chin to nas.	Nas-pros.	Lth. nose	Brdth. nose	Lth. ear	Brdth. ear	Eyes	Hair	Skin
41	90	170	110	67	53	29	52	32	15	4	12
42	101	185	115	78	55	32	56	27	12	10	3
43	101	175	112	69	51	32	61	31	4	5	7
44	93	171	115	75	54	32	59	28	12	9	10
45	107	162	110	63	50	35	60	30	4	5	7
46	105	173	118	76	57	34	56	30	13	7	3
47	100	175	120	74	56	33	54	28	7	8	10
48	101	171	121	75	58	28	55	27	14	8	3
49	105	185	123	78	59	31	60	31	3	5	7
50	103	172	116	74	55	30	55	29	10	5	9
51	94	175	112	67	49	33	57	30	13	8	7
52	100	160	108	69	53	33	62	32	5	5	12
53	99	176	118	62	51	31	58	30	15	7	7
54	98	179	123	73	52	31	59	30	8	4	10
55	99	181	125	74	55	35	65	33	15	26	11
56	103	187	126	83	59	36	59	28	6	5	12
57	102	169	115	74	56	33	59	31	12	7	11
58	97	177	113	69	51	34	54	30	3	5	11
59	97	176	115	71	51	34	58	28	13	8	3
60	97	175	114	73	55	30	57	30	8	8	8
61	91	163	108	69	49	31	55	26	4	5	11
62	98	179	116	73	56	31	59	33	13	9	3
63	95	167	110	70	51	30	62	30	13	7	7
64	95	188	122	76	60	28	58	29	15	8	3
65	96	185	122	76	60	29	58	31	15	8	3
66	99	170	118	71	53	29	49	26	5	4	13
67	94	168	111	73	56	29	62	30	13	7	10
68	99	167	120	75	55	30	62	26	13	8	7
69	97	177	122	77	57	34	61	27	5	9	12
70	102	180	119	75	56	32	63	31	5	6	11
71	91	180	123	74	51	32	58	29	13	8	3
72	101	176	112	68	52	30	56	26	7	9	7
73	108	181	122	76	56	37	60	30	8	26	7
74	104	183	123	75	57	32	60	30	5	5	10
75	109	171	119	75	55	36	58	30	4	4	12
76	86	187	125	74	53	31	57	25	5	6	3
77	93	184	118	76	56	28	61	30	15	8	11
78	84	165	110	73	55	30	55	25	15	25	9
79	97	182	120	76	55	33	56	29	4	7	13
80	108	181	122	75	55	34	62	30	8	9	11

No.	Measurements of head and face								Color of		
	Brdth. mand.	Chin to hair	Chin to nas.	Nas-pros.	Lth. nose	Brdth. nose	Lth. ear	Brdth. ear	Eyes	Hair	Skin
81	84	186	127	76	55	30	56	33	15	8	3
82	98	175	112	71	56	29	55	30	13	7	7
83	85	182	117	74	55	33	57	31	15	8	11
84	101	168	104	65	49	35	59	28	11	6	10
85	90	176	113	72	52	33	57	28	4	4	14
86	100	185	125	73	54	35	64	30	15	9	10
87	99	184	119	72	57	30	57	34	15	9	10
88	96	179	113	73	55	35	61	29	7	5	10
89	104	165	104	65	47	33	57	31	6	13	11
90	97	177	119	72	55	33	59	30	8	8	10
91	105	183	118	69	44	33	58	29	12	7	12
92	97	165	115	74	55	32	62	29	16	7	7
93	100	171	110	71	51	31	61	27	5	9	11
94	100	183	118	76	55	32	58	28	10	10	3
95	94	162	109	67	48	29	54	32	3	5	13
96	89	175	115	71	55	31	65	33	3	5	12
97	97	173	113	72	52	33	65	29	8	4	8
98	99	187	121	73	52	32	67	31	16	8	3
99	88	186	121	77	56	28	56	27	9	5	11
100	94	170	110	67	49	32	52	26	10	8	3

INDEX