SKELETAL PARTS: THE SKULL

The art of measuring the skeletal parts differs in many respects from that of measuring the living and is, in fact, to a degree a field of its own. It is, moreover, a particularly attractive field, for we deal here with specimens that are not masked by other tissues, that can be handled cleanly and easily, and that are mostly completely at our disposal for reference or additional observation.

The most interesting and important part of the skeleton is naturally the cranium, and this has received from the beginnings of anthropology the most assiduous attention. The preoccupation of anthropologists with the skull,[1] particularly since the repeated discoveries of the remains of early man, has in fact been such as to overshadow the study of the rest of the skeleton, with the result that methods relating to research on the long and other bones are with some exceptions less developed and standardized than those on the skull. Yet these secondary skeletal parts are a mine of information of anthropological interest, and as time goes on they cannot but receive more and more attention. The time for a selection of the best methods of measuring as well as observation on the more important of these parts is at hand, and in the final section of this series an attempt will be made in this direction. The present section is devoted mainly to the cranium.

Craniometry

Efforts at a development of a scientific system of cranial measurements and observations date from well before the beginning of the nineteenth century. The most serious and at the same time successful steps in this direction were, however, those of Samuel G. Morton in Philadelphia in the late thirties of that century, of Anders Retzius in Sweden (1842–1860), and especially those of Paul Broca in France, from the early sixties onward. Broca's system, which was eventually comprised in the "Instructions craniologiques et craniométriques"

[1] See bibliographies in "International Catalogue of Scientific literature," in Martin's "Lehrbuch d. Anthropologie," in author's "Physical Anthropology in the United States" 8°, Philadelphia, 1919), and in the Catalogue of the Library of the Surgeon General, U. S. A.

(8°, Paris, 1875), is, with some modifications and additions, in use to this day.

The most noteworthy contributions to the subjects of craniometry and craniology since Broca are those of Topinard,[1] Turner,[2] Schmidt,[3] Török[4], Welcker,[5] and finally, Martin[6]; but due credit belongs to many earlier as well as later well known workers, such as Blumenbach, de Baer, Lucae, Meigs, Soemmering, Wentzel Gruber, Quatrefages, Hamy, Geoffroy St. Hilaire, Flower, Davis, Thurman, Hovelacque, Virchow, and others, not to mention the most recent or still living, such as Hervé, Ranke, Schwalbe, Gustaf Retzius, Sergi, Manouvrier, Matiegka, Le Double, Boule, Giuffrida-Ruggeri, etc.

The total results of all this work on the skull are not only a great mass of data from all parts of the world, but also an elaborate and profuse technique of measurements. Many of these measurements are now, however, of little more than historical value, having been replaced by others or abandoned. Of what remains, the main part has been standardized by the International Anthropometric Convention of Monaco.

The cranial measurements that will be dealt with here are essentially those of the Monaco Agreement; but some of those included in the Agreement have since become quite obsolete, while in a few instances it is now possible to make useful additions, so that a simple reference to the Agreement would not be sufficient. The blanks to be given resemble in essentials those employed on the living (pp. 63–5). For brevity, repetition of definitions, etc., will be avoided, author's notes being restricted to such explanations as will assist the student. A number of measurements included call for special instruments which will be described in that connection. No agreement has yet been attempted as to the relative importance and definition of descriptive characters, and what will here be given in that line is of a more or less tentative nature.

Before beginning with either measurements or descriptive terms, however, it will be necessary to give due consideration to several preliminary procedures, some of which are of considerable importance.

[1] "Élements d'Anthropologie générale," 8°, Paris, 1885.

[2] Challenger Reports, Part 29, London, 1884.

[3] "Anthropologische Methoden," 12°, Leipzig, 1888.

[4] "Grundzüge einer systematischen Kraniometrie," 8°, Stuttgart, 1890.

[5] Valuable contributions in anthropological periodicals, particularly the Archiv für Anthropologie.

[6] "Lehrbuch der Anthropologie," 8°, Jena, 1914.

Preparation of Specimens.—Before a series of crania (or bones) can be submitted to measurement or examination, the specimens must be not only well *cleaned*, but also carefully *repaired*, which is interesting work and at times calling for not a little ingenuity. For repair, about the most suitable cement is a thick paste made from fish glue, or from Page's liquid glue, with plaster-of-paris and pigment. A box of dry sand in which to place the skulls or bones while the cement is setting will also be required.

The specimens, furthermore, must be numbered and catalogued, otherwise there would inevitably be confusion. The method of numbering is immaterial, so long as the numbers do not duplicate others in the collection. The number, tribe, locality, and sex are marked with indelible ink in the most convenient location, which in the skull is perhaps the antero-inferior angle of the left parietal; and all specimens of one kind in the collection are marked in the same place. If the bone is scaly or too rough, a small parallelogram is covered neatly with oil paint and the mark made on this.

Sexing.[1]—In adults, the determination of sex, from the skull alone, while generally offering few difficulties to the well-trained observer, is not equally easy in all races, or in all individuals.

A typical masculine skull differs in practically every feature from

[1] The most important contributions to this subject (outside of the various text-books on Anatomy and Anthropology) are:

Bartels (P.), "Ueber Geschlechtsunterschiede am Schädel," Thes., Berlin, 1897.

Dureau (A.), "Des caractères sexuels du crâne humain," *Rev. d'Anthrop.*, 1873, II, 475.

Ecker (A.), "Ueber eine charakteristische Eigentümlichkeit in der Form des weiblichen Schädels und deren Bedeutung für die vergleichende Anthropologie," *Arch f. Anthrop.*, 1866, I, 81.

Manouvrier (L.), "Sur la grandeur du front et des principales régions du crâne chez l'homme et chez la femme," *C. R. Assoc. Franc.* p. *l'Avanc. d. Sc.*, 1882.

Mantegazza (P.), "Dei caratteri sessuale del cranio umano," *Arch. p. Antrop.*, 1872, II, 11.—"Studii di craniologia sessuale," *Arch. p. Antrop.*, 1875, V, 200.

Möbius (P. J.), "Ueber die Verschiedenheit männlicher und weiblicher Schädel," *Arch. f. Anthrop.*, 1907, N. F. VI, 1.

Panichi (R.), "Ricerche di craniologia sessuale," *Arch. p. Antrop.*, 1892, XX, 49.

Pittard (E.), Les segments crâniens chez l'homme et chez la femme." *Arch. d. Sc. Phys. & Nat.*, 1899, 1900.—"Quelques comparaisons sexuelles de crânes anciens de la vallée du Rhône (Valais)," *L'Anthrop.*, 1900, XI, 179.—"Comparaisons sexuelles dans une série de 795 crânes de brachycéphales alpins," *Bull. Soc. d'Anthrop.*, Lyon, 1910, XXVIII, 119.—"Analyse et comparaisons sexuelles de quelques grandeurs du crâne et de la face chez les Tsiganes," *C. R. Acad. Sc. Paris*, 1911, T. 152, 208.

Welcker (H.), "Geschlechtseigentümlichkeiten des Schädels," *Arch. f. Anthrop.*, 1866, I, 120 *et seq.*

the typical feminine one. It is larger on the whole and in all its components, it is heavier, and all its muscular insertions as well as other features are more strongly marked or developed. But in no human group is there any regular, precise line of demarcation between the male and female characteristics, taken individually or even collectively. In every lot we find male skulls which in some or all of their features are less masculine than the average, and similarly there will be female skulls that in some or all of their parts approach the masculine. Instead of a sharp dividing line we have interdigitation and continuity, as a result of which in certain cases the sexual identification of a specimen with all our efforts remains uncertain. In rare cases, even, a female skull may show more pronounced masculine characteristics than some of the less well developed male crania, and vice versa, which may lead to errors in classification.

On the whole it may be said that an experienced and careful observer will have little if any difficulty in correctly identifying over 80 per cent of the crania, with which there is neither the lower jaw nor any other part of the skeleton to assist him; that this proportion will approximate 90 per cent where a well-preserved lower jaw is present; and that it will reach over 96 per cent where we have the whole skeleton. But out of each hundred there will still remain one or two skeletons which, even though complete, show such indefinite sexual characteristics that it will be impossible to identify them as either male or female with certainty.

Given a skull for sexual identification, the observer notes first the size of the vault as well as that of the face; a large size speaks normally for a male and a small size for a female. The features observed next, and in the order named, are the supraorbital ridges, the mastoids, the zygomæ, the occipital crests, the lower jaw, the palate and the teeth, the facial "physiognomy," and the base of the skull.

The *supraorbital ridges* are on the average decidedly more developed in the males than in the females. If we should characterize them as we do in practice by the terms "traces," "slight," "moderate," "medium," "pronounced," and "excessive," the male skulls will show ridges from moderate to excessive, while the female skulls will be restricted to those of from traces to moderate. Pronounced or excessive ridges do not occur in females, nor are ridges that could be characterized as only "traces" to be found in adult males. But we may have "slight" ridges in a male subadult or even adult.

The *mastoids* may be "small," "moderate," "medium," "large,"

or "excessive." Male mastoids generally range from medium to large, female mastoids from small to medium. Small mastoids do not occur in males nor do large or excessive mastoids occur in females.

The *zygomæ* may be "slender," "moderate," "medium," "strong," or "massive." They range in males from medium to massive, in females from slender to medium.

The *occipital crests* when well or markedly developed as a rule indicate a male. In females they range from "submedium" to "absent."

The *lower jaw* in the male shows on the average greater size, thickness, and weight as a whole, a higher body throughout, a higher symphysis especially, a broader ascending branch, an angle less obtuse than in the female, and strong condyles. A lower jaw of moderate size and strength, with a low symphysis, a rounded chin (a square chin points to male sex), a relatively low body, only moderately broad ascending ramus, delicate or but moderately strong condyles, and an angle of more than 125°, may safely be diagnosed as feminine.

The *palate* in the male skull is usually larger and appreciably broader, and the *teeth* in the male are on the average perceptibly larger than those in the female.

The "*physiognomy*" of the face, or the impression that the face with the lower jaw in position makes upon the experienced observer, is a characteristic of considerable importance in sex determination. The average male skull presents a decidedly more masculine physiognomy than does the average female cranium. This is due to a combination of factors which should be briefly enumerated. The forehead in the female skull is usually more vertical than in the male, and smoother; the borders of the orbits in the average male skull are dull, in the average female sharp; the nasal process of the frontal, the nasal bones, the malars, and the upper maxillae as a whole, are larger and stouter in the male than in the female; and the height of the upper alveolar process, between the nasal aperture and the front teeth, is greater in the male. The nasal aperture, moreover, is less high, often relatively somewhat broader, and more delicately moulded in the female. All this, together with the sexual characteristics of the lower jaw, when present, gives the face a certain expression which is of great help in identifying the sex of the skull. Unfortunately the lower jaw is often missing, and the upper face damaged or affected by senile changes, all of which diminishes or disturbs the sexual expression.

Thickness of the vault, alone, is of no decisive value in sexual identification, for while the bones of the male are on the average slightly thicker, individual thick and massive vaults are encountered in both sexes, especially among primitive peoples.

The *base of the skull* presents a complex of structures which as a whole show stronger development and larger dimensions in the male than in the female. The foramina, too, are in general larger in the male.

Sexual Characteristics of Other Skeletal Parts.—As in the sexual identification of the skull we are often obliged to consult the rest of the skeleton, if at hand, the principal sex determining characteristics of the latter may well be dealt with in this connection.

In detailed examinations we find that every bone in the body offers certain sexual differences. The most important skeletal parts for sexual identification aside from the skull are, however, the pelvis, the long bones, and the larger of the remaining parts.

As to the pelvis,[1] the important sexual characteristics which it presents may conveniently be shown as follows:

	Male	Female
Subpubic arch	V-shaped	Broader (approaching U-shaped) with diverging branches
Ischio-pubic rami	But slightly everted	Markedly and characteristically everted
Symphysis	High	Lower
Obturator foramina	Large	Smaller, more triangular
Acetabula	Large	Smaller
Greater sciatic notch	Rather close and deep	Wide and shallow
Ilia	High, more upright	Lower, more flaring in upper portion
Sacro-iliac articulations	Large	Smaller, more oblique

[1] See (besides the modern textbooks on Anatomy, and Obstetrics):

Emmons (A. B.), "A study of the variations in the female pelvis," etc. *Biometrica*, 1912, IX, 33–57.

Hennig (C.), "Das Rassenbecken," *Arch. f. Anthrop.*, 1885, XVI, 161–228 (Bibl.).

Runge (G.), "Shape of female pelvis in different races," 8°, St. Petersburg, 1888; 80 pp.

Sergi (G.), "L'indice ilio-pelvico o indice sessuale nel bacino delle rase umane," *La Clin. Ost.*, 1899, I; 7pp.

Thompson (A.), "The sexual differences of the fœtal pelvis," *J. Anat. and Physiol.*, Lond., 1899, XXXIII, 359–380.

Verneau (R.), "Le bassin dans les sexes et dans les races," 8°, Paris, 1875, 156 pp.

Waldeyer (W.), "Das Becken." 8°, Bonn, 1899, 600 pp.

Zaaijer (T.), "Der Sulcus preauricularis ossis ilei," *Verh. k. Akad. Wet.*, Amsterdam, 1893, 23 pp.

Preauricular sulcus	Infrequent	More common and better developed
Sacrum	Relatively high and narrow	Shorter and broader, more obliquely set, less curved in upper portion; sacro-vertebral angle more prominent
Pelvis as a whole	Strong, heavy, marked muscular impressions	Less massive, smoother
Brim	Heart-shaped	More circular (or elliptic), more spacious
True pelvis	Relatively smaller	More oblique, shallow and spacious, less encroached upon by ischiac spines

However, none of the above characteristics are wholly constant, and there are pelves so intermediate that a correct diagnosis of sex from them alone cannot be made with certainty.

As to the *long bones*, those of the male are generally larger and heavier than those of the female and have more pronounced muscular ridges, tuberosities and impressions; but the most important and striking sexual differences lie in their articular extremities, which in the bones of the male are in general both absolutely and relatively larger than in the female. A femur or a humerus with a small head or condyles cannot be masculine, neither can bones with relatively large heads or condyles be feminine. These differences are of great help in sexing the skeleton or individual bones. However there are also intermediary grades of development which might leave us uncertain if we had the long bone only.[1]

As to the remaining larger bones of the body, the most important for sexual identification are the sternum, scapulæ, ribs, the spine as a whole, some of the vertebrae such as the atlas, axis, and the fifth lumbar, the patella, the calcaneus, and the first phalanx of the great toe. In general they all show larger size, greater weight and stronger development of muscular attachments in the male; and they present various individual features which differ more or less in the two sexes, such as the relatively longer manubrium in the female, a larger glenoid cavity in the male, etc. Their utilization for sexual identification stipulates naturally a special acquaintance with these various bones.

[1] Consult Dwight (Thos.), "Range and Significance of Variation in the human skeleton," *Bost. Med. and Surg. J.*, July, 1894, 73 et seq.—"The size of the articular surfaces of the long bones as characteristic of sex," *Am. J. Anat.*, 1904, IV, 19–31.

Dorsey (Geo. A.), "A sexual study of the size of the articular surfaces of the long bones in aboriginal American skeletons," *Bost. Med. and Surg. J.*, July 22, 1897.

Even the smaller bones, such as those of the tarsus, may help in this connection.

In addition to the differences due to the general development of bones, various parts of the skeleton occasionally present features as for example perforation of the septum in the humerus, third condyle on the femur, a teres major process of the scapula, etc., which do not occur with the same frequency in the males as in the females; but as they may occur in both, their presence or absence in individual cases is not of decisive value. Furthermore, all the bones of the skeleton when studied in lots will show characteristic sexual differences of anthropometric nature, in absolute dimensions as well as indices; but except in extremes these again are of only secondary value in the case of individual bones.[1]

In subadults, determination of sex is mostly hazardous, nevertheless there are a certain proportion of cases in which it is possible. But as the age descends the difficulties of identification rapidly increase, until when we reach puberty and below, it becomes in general very risky, if not impossible.

Estimation of Age.—A correct estimation of the age of a skeleton is of a much greater medico-legal than anthropological importance; but by mastering the details, for which our science is favorably situated, the anthropologist may occasionally be of substantial aid to legal medicine.

For the anthropologist himself it generally suffices to determine whether the skull or skeleton is subadult, adult, or senile, and his main criteria for these purposes are the state of the basilar suture, that of the epiphyses of the long bones, the stage of dentition, the condition of the teeth and alveolar processes, and the state of the sutures of the vault of the skull.

Of all the marks that the adult stage of life has been reached, the most handy and reliable is the *occlusion of the basilar (basisphenoid) suture;* and the value of this sign is furthermore enhanced by the rarity with which abnormal processes affect this articulation. But the basi-sphenoid articulation may be opened mechanically, through posthumous changes in the bones or through violence, and the student must be on the lookout not to mistake such a condition, which to the unaided eye may simulate very closely the normal suture, for the latter.

The *epiphyses* of the long (and other) bones are normally all united with their diaphyses by the end of the twenty-fifth year. The fol-

[1] See author's "Physical Anthropology of the Lenape," etc., Bull. 62, Bur. Amer. Ethnol., Wash., 1916.

lowing figures give approximations to the exact time of synostosis in the different cases, according to modern Anatomies. They again can be of but a restricted use to the anthropologist.

OSSIFICATION (COMPLETED)

		Year
Basilar suture		20–25
Humerus:	upper	20–25
	lower	18–19
Femur:	upper	18–20
	lower	20–22
Tibia:	upper	20–24
	lower	18
Ulna:	upper	16
	lower	20–23
Radius:	upper	17–20
	lower	20–25
Fibula:	upper	22–25
	lower	19–20
Scapula		20–25
Clavicle, sternal end		25
Sternum		20–25
Ribs		25
Vertebrae		25
Atlas		18
Sacrum (union of uppermost segments)		25–30
Ossa innominata		20–25
Phalanges		18–20

The *eruption of deciduous teeth* among Whites is generally completed before the end of the third, that of the *permanent teeth* before the thirtieth year of life. Among primitive peoples (possibly even primitive Whites), the process, at least so far as the permanent teeth are concerned, is somewhat speedier, being with some exceptions accomplished by or even before the twenty second year.[1] A full set of teeth in a skull is therefore a good sign that adult life has been reached, or nearly reached; but an absence of one or two third molars may exist in the white, and more rarely even in a primitive man, well into the adult stage, and such teeth may fail to appear altogether. The following table gives the periods of eruption of both sets of teeth among civilized Whites. On account of the length of the period of eruption of the individual teeth the data will be also of but limited use.

ERUPTION OF TEETH, IN WHITES[2]

1st Dentition	Months	*Permanent Dentition*[3]	Years
Median Incisor, lower	4– 8	First Molar, lower	4– 7
Median Incisor, upper	8–11	First Molar, upper	5– 8

[1] See Suk (V.), "Eruption and decay of permanent teeth in Whites and Negroes, with comparative remarks on other races," AM. J. PHYS. ANTHROP., 1919, II, No. 4, 352.

[2] After Bean, Bednář, Cherot, Gray, Matiegka and Suk, Roese, Steiner, Vogel, Welcker, etc.

[3] Exact order of eruption of permanent canines and premolars is still slightly uncertain.

	Months
Lateral Incisor, upper	8–11
Lateral Incisor, lower	12–15
First Molar, upper	9–21
First Molar, lower	12–21
Canine, upper	16–24
Canine, lower	16–25
Second Molar, upper	20–36
Second Molar, lower	20–36

	Years
Median Incisor, lower	5– 8
Median Incisor, upper	5– 8
Lateral Incisor, lower	6–10
Lateral Incisor, upper	6–10
Anterior Premolar, upper	7–14
Canine, lower	8–14
Anterior Premolar, lower	8–15
Posterior Premolar, upper	9–15
Posterior Premolar, lower	9–15
Canine, upper	9–16
Second Molar, lower	10–17
Second Molar, upper	10–17
Third Molar, lower	15–30
Third Molar, upper	17–30

The pubic articulation shows important changes with age.[1]

A valuable indication as to advancing age is furnished to us by the *wear of the teeth*.[2] In Whites this seldom commences before the thirty-fifth or is marked before the fiftieth year of age, and in many individuals of the more cultured classes it may remain slight up to old age; but among grain-eating, primitive peoples, such as the American Indians, wear may commence even before the adult life has been reached, be very marked at fifty, and reach an extreme grade after sixty-five. Partial wearing, due to peculiar habits, has of course but little value in this connection.

The *obliteration of the cranial sutures* has long been relied upon as a help in estimating the age of the subject, and is useful when taken conjointly with other characters. Under normal conditions, i. e. in subjects who have not been affected by rickets or other generalized pathological processes, synostosis of the bones of the vault does not commence until well after adult life has been reached, and in some individuals some or all of the bones of the vault may remain free until advanced age. On the average, however, we may expect to find some traces of synostosis ventrally about the thirtieth, and dorsally about the fortieth year of life. In view of the difficulties of a proper endoscopic examination, the dorsal signs of obliteration are the only ones with which the anthropologist under ordinary circumstances needs to concern himself. The obliteration here may begin in the posterior

[1] See Todd (T. Wingate), "Age changes in the Pubic Bone," *Am. J. Phys. Anthrop.*, 1920, III, No. 3, 285.

[2] See Broca (P.), *Bull. Soc. d'Anthrop.* Paris, 1879, S. 3, II, 342; Instructions craniolog., etc., 1875, 132.

third of the sagittal suture, or in the distal portions (below the temporal crests) of the coronal—there are some racial as well as individual differences in this respect. A complete obliteration of the coronal, sagittal, and lambdoid sutures under ordinary conditions is reached only in advanced age, after seventy, and in fact is seldom fully accomplished even then. The temporal articulations, with the exception of that with the occipital, are the last to ossify. A complete synostosis of all the articulations of the bones of the vault at any age would justify a suspicion of some abnormality. With ample experience, and taking the condition of the sutures and teeth together, we may correctly estimate the age of the adult subject to within, perhaps, ten years.[1]

As *signs of advanced senility*, may be named a diminution in weight of the skull and bones, with more or less rarefaction of the bone structure (particularly in the long bones of the lower limbs and the spine); extensive loss of teeth and marked absorption of the alveolar processes; and disseminated marginal exostoses of the lumbar and other vertebrae. This latter condition, although usually looked upon as pathological, is so common in senile skeletons of all races that it may well be regarded as a part of the process of skeletal senile involution, becoming only secondarily, or through its irregularities and complications, pathological.

In addition to the above the vault of the skull may in advanced age occasionally show a more or less marked absorption of the bony tissue (diploë) of the parietals above the temporal ridges, with a consequent bilateral, antero-posterior depression. The lower jaw may in instances be reduced to a mere frail shell, with greatly widened angles; while the upper alveolar process may be completely absorbed and the loss involve even a part of the nasal floor. But these extreme mani-

[1] See in this connection, Dwight (Thos.), "The closure of the cranial sutures as a sign of age," *Bost. Med. and Surg. J.*, 1890, 389.

Frederic (J.), "Untersuchungen ü. d. normale Obliteration der Schädelnähte," *Z. f. Morph. and Anthrop.*, 1906, IX, 273; 1909, XII, 371.

Parsons (F. G.) and C. R. Box, "The relation of the cranial sutures to age," *J. Anthrop. Inst.*, 1905, XXXV, 30.

Pommerol, (J.), "Recherches sur la synostose des os du crâne," *Bull. Soc. Anthrop. Paris*, 1869, S. 2, IV, 502; and Thèse, Paris.

Ribbe (F. C.), "Étude sur l'ordre d'oblitération des sutures du crâne dans les races humaines," *Thèse*, Paris, and *Rev. d'Anthrop.*, 1885, S. 2, VIII, 348.

Welcker (H.), "Altersbestimmung der Schädel," *Arch. f. Anthrop.*, 1866, I, 113.

Zanolli (V.), "Studio sulla obliterazione delle suture craniche," *Atti Soc. rom. Antrop.*, 1908, XIV, 13.

festations of senile resorption are of little value as indices of the age of the individual in years.[1]

Identification of Parts.—Given a series of crania, and perhaps other bones, for examination, we frequently find that some of the lower jaws have become detached from the skulls, and various bones separated from the skeletons to which they belong. We may further find individual crania, or even larger admixture, of a different type from that of the rest of the collection. Our object naturally will be to properly fit the stray parts, and segregate the heterogeneous specimens. This once more demands considerable care and experience.

The fitting of the lower jaw to its skull is fairly easy if we have to deal with only a few specimens; but in larger collections, and even in some individual cases where more or less warping of the lower jaw has taken place, the task may be quite difficult. The main guidance of the student will be the fit of the teeth, the fit of the condyles, the color and mottling of the specimens, and various conditions and peculiarities of the teeth. He will find a similar or compensatory wear of the teeth in the two jaws of the same individual; a correspondence of more or less extruded or unworn teeth (especially the third molar) in one jaw, to absence of opposite tooth in the other; a similar staining of or concretions about the teeth; etc. But there may be anomalies in one (especially the upper) jaw for the counterparts of which he would vainly look in the other.

As to other parts of the skeleton, which may be touched upon in this place, we can only hope to establish whether or not a certain bone

[1] Consult: Allen (Harrison), "On the effects of disease and senility as illustrated in the bones and teeth of mammals," *Science*, 1897, V, 289–294.

Broussé (A.), "De l'involution sénile," 8°, Paris, 1886.

Féré (C. H.), "Sur l'atrophie sénile symmétrique des pariétaux," *Bull. Soc. d'Anthrop.*, Paris, 1876, S. 2, XI, 423. (cont'd next p.)

Humphry (C. M.), "Senile hypertrophy and senile atrophy of the skull," *J. Anat. and Physiol.*, London, 1890, XXIV, 598.

Le Courtois, "Modifications morphologiques de la voûte crânienne osseuse suivant l'âge et le type crânien," *Bull. Soc. d'Anthrop.*, Paris, 1870, S. 2, V, 607–620.

Possi (Senile changes in the skull). *Dict. Encycl. d. Sc. Méd.*, XXII, 492.

Sauvage (H.), "Note sur l'état sénile du crâne," *Bull. Soc. d'Anthrop.*, Paris, 1870, S. 2, V, 576. Also sep., Paris, 1870, 132 pp.

Smith (G. Elliot), "The causation of the symmetrical thinning of parietal bones in ancient Egyptians," *J. Anat. and Physiol.*, London, 1907, XLI, 232.

Thomas (O.), "Notes on a striking instance of cranial variation due to age," *Proc. Sci. Meetings Zoöl. Soc.*, London, 1886, P. I, 125 pp.

Virchow (R.), "Ueber die Involutionskrankheit (Malum senile) der platten Knochen, namentlich des Schädels," *Ges. Abh.*, 1856.

belongs to a skeleton in question by its fit with other bones in articulation, and by resemblances in color, size, shape, muscular insertions, processes, and peculiarities, with the corresponding bone of the opposite side of the body. With the exception of the atlas we are never in a position to absolutely identify a given stray bone, or even a whole skeleton, with a given skull. Occasionally we find it difficult to even pair or place individual bones; but special features and measurements help greatly in this direction.

Recognition of distinct racial types in a collection, demands especially careful procedure. The skull of a typical White, a typical Negro, a typical Eskimo, or a typical American Indian, may be readily and reliably identified, wherever found by the expert student; and in a smaller measure this is also true of some other parts of the skeleton. But when it comes to a recognition of crania or bones of mixed-bloods, or of closely related racial types, we face considerable uncertainties. The safest rule in all cases is for the observer to set aside from his series any skull or skeleton concerning the anthropological identity of which he is in serious doubt. He will bear in mind, of course, that among all peoples there exists in every feature a wide range of normal variation.

Determination of Normality.—A normal skull (or a normal bone) is that which has not been modified in shape, size, or any other manner, mechanically or through disease.

Mechanically a skull may be modified through injury, artificial or accidental deformation in life, or posthumous deformation.

Deformations through injury are readily recognizable, and in general are of small importance to anthropology. But extensive injuries of the vault and especially of the face, or injuries followed by serious alterations in the bone, may spoil the specimen more or less for study.

Artificial and accidental deformations in life have been dealt with previously (pp. 47–8), and the observations made in that connection apply essentially also to the skull. The best way to appreciate lesser grades of deformations is to pass the hand snugly over the top of the skull from before backwards; the practiced sense of touch is even more reliable in these cases than the sense of sight, and will be of much assistance.

Posthumous deformations are fortunately not frequent, but must nevertheless be reckoned with, and that above all in imperfect skulls and with the lower jaw. The degree of such deformation, with or

even without fracture, is sometimes remarkable. As a result the vault of a skull may assume extreme steno-dolichocephalic or plagiocephalic appearance, and the arch of the lower jaw be considerably compressed—conditions which could easily deceive the inexperienced.[1] Posthumous deformations of the long bones may simulate curvatures; in other parts they are immaterial.

Deformations caused by disease[2] are most commonly those of rickets, or hydrocephalus. Microcephaly, akromegaly, diffuse osteoporosis, and leontiasis ossea, each represent or may produce marked alterations in the shape, size, weight, and individual features of the skull. But recognition of these conditions when well developed offers no difficulties. The bones of the skeleton may be altered through dwarfism, cretinism, giantism, acromegaly, syphilis, inflammations, tumors, osteomalacia, tuberculosis, and above all, as already mentioned, by rachitis.

Measurements of the Skull

As for measurements on the living, so for those on the skull, the observer needs a well-lighted place and one where he will be least disturbed. He will need ample table space, which, however, may in part be improvised with boards. He should have at hand a camera, a

[1] See Tarenetsky (A. J.), Postmortem alterations and damage of skulls (in Russian) *Proc. Anthrop. Sect. Milit.-Med. Acad.* St. Petersb., 1895, I, 19.

[2] See Backman (G.), "Ueber die Scaphocephalie," *Anat. Hefte*, H. 112, Wiesbaden, 1908, 219–270 (with extensive bibliography).—"Ueber Bathro- und Clinocephalie," *Ibid.*, H. 140, 1912, 495–571 (Bibl.).

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Pommerol (F.), "Recherches sur la synostose des os du crâne, considérée an point de vue normal et pathologique ches les différents races humaines." Thèse, Paris, 1869, 116 pp.

Virchow (R.), Gesam. Abh., 1856.

stereograph or some other form of large drawing apparatus, and a mounted prism ("camera lucida"). He will need a suitable stuffed leather or canvas ring as skull support. And, as in work on the living, he will need properly prepared blanks (fig. 18, p. 119).

The specimens to be examined are separated first according to kind, then according to sex, and are then arranged by numbers. All of this facilitates work.

The blanks should be based on the same general principles as those for measurements and observations on the living (see p. 63 et seq.). Separate blanks are required for the skulls and for each kind of bone. To save work these blanks may be printed; or they may be prepared on good sized sheets marked in squares large enough to readily accommodate the records either in figures or in abbreviations. Sample blanks are given on the following page.

Selection of Measurements.—The same general rules that apply in this respect to the living (p. 61) apply also to the skull and rest of the skeleton and need not be repeated here. The skeletal collections, however, are for the most part fully and continuously at our disposal, so that they may be used again and again, serving for a series of studies besides that the object of which was a general description. The student may thus in cases require but a single measurement, or a special observation on a single feature of a skull or a bone, and he will prepare his scheme to suit the occasion.

When the object is a general description of a series of crania (or skeletons), the observer will naturally endeavor to show first those features which are of the greatest importance from the standpoint of race or group; and these are usually the size, shape, and peculiarities of the specimen as a whole, and in its main parts. In the case of the skull, he will therefore measure the principal dimensions of the vault, with its capacity; the main dimensions of the face, lower jaw, palate and teeth; and take notes on the form of the vault, face, nose and orbits. He will add such visual observations as may complete in all essential points the picture of the specimen which he wishes to transmit so that this may be properly conveyed to his fellow workers and used in comparison. The concrete object of the work, as here touched upon, should not be forgotten in the maze of details. A list of measurements and observations used for these purposes by the author, is here given:

Instruments.—Craniometry, as well as osteometry, has a series of its own instruments. The small sliding compass (c. glissière), the regular spreading calipers (c. d'épaisseur), and the anthropometric

Crania. A.

Sex:———

Catalogue No.	Collection	Locality	Approximate Age of Subject.	Deformation	Vault: Diam. Antero-posterior maxim.	Vault: Diam. Lateral maxim.	Vault: Basion-Bregma Height	Vault: Cranial Index	Vault: Mean Height Index $\frac{H}{\text{mean of } L+B}$	Vault: Cranial Module	Capacity in c.c. (Hrdlička's Method)	Thickness of Left Parietal 1.0 cm. above T.-P. Suture

Crania. B.

Sex:———

Catalogue No.	Diameter Frontal min.	Face: Menton-Nasion Height (a)	Face: Alveolar Point-Nasion Height (b)	Face: Diam. Bizygomatic maxim. (c)	Face: Facial Index, Total $\left(\frac{a \times 100}{c}\right)$	Face: Facial Index, Upper $\left(\frac{b \times 100}{c}\right)$	Base: Basion-Alveolar Point (z)	Base: Basion-Subnasal Point (y)	Base: Basion-Nasion (s)	Facial Angle (Angle between z and Alveolar Point-Nasion Line)	Alveolar Angle (Angle between z and Alveolar Pt.-Subnas. Pt. Line)

Crania. C.

Sex:———

Catalogue No.	Nasal Apperture: Height	Nasal Apperture: Breadth Maxim.	Nasal Apperture: Nasal Index	Orbits: Height, Right, Left,	Orbits: Breadth, Right, Left,	Orbits: Orbital Index, Mean	Palate: External Length (a)	Palate: External Breadth, maxim. (b)	Palate: Palatal Index $\left(\frac{b \times 100}{a}\right)$	Lower Jaw: Diam. Bigonial	Lower Jaw: Angle of Lower Jaw, mean	Lower Jaw: Height of Symphysis	Lower Jaw: Thickness of Horiz. Ramus bet. 1 & 2 Molars r. l.	Miscell.: Foramen Magnum, Mean Diam.	Circumference maxim. (Above Ridges)	Arcs: Nasion-Opisthion	Arcs: Na.-Eg.	Arcs: Eg.-Ld.	Arcs: Ld.-Opisth.

tape, are the same as for measurements on the living; but in addition the student will need an outfit for measuring the skull capacity; one for drawing; a Broca's mandibular goniometer; a transparent goniometer; and instruments for special purposes, such as the occipital goniometer, small sharp pointed calipers, an endocompass, curved brass probe, etc. For measurements on other bones of the skeleton he will need, in addition, the standard osteometric board with a block, a pelviphore, and apparatus for measuring the torsion of the humerus. With a few exceptions, these appliances are described and illustrated in Broca's "Instructions Craniologiques et Craniométriques" (Paris, 1875); in Topinard's "Éléments d'Anthropologie Générale" (Paris, 1885); in Martin's "Lehrbuch der Anthropologie" (Jena, 1914); and in Mathieu's, Collin's, and Hermann's Catalogues of anthropometric instruments. As far as additional description or remarks may be called for, they will be made most suitably in connection with the individual measurements.

Landmarks.—Before proceeding to the description of methods, it will be useful to give a list of the landmarks on the skull and their definitions. We may here conveniently draw on Topinard's and Martin's textbooks and on Cunningham's and other modern Anatomies, which include lists of this nature; but it may be of some advantage to give the terms in alphabetical order, and in a few instances to supplement the definitions.

Alveolar Point (or Prosthion).—The term "alveolar point" has a long priority of usage and no valid reason is apparent why it should be changed. It is the lowest point of the upper alveolar arch, between the median incisors. Broca defined it as the lower extremity of the intermaxillary suture, but occasionally the bone on one side or the other projects slightly beyond the suture, so that the above definition is preferable.

Asterion.—The point of meeting of the temporo-parietal, temporo-occipital and lambdoid sutures.

Basion.—The middle of the anterior margin of the foramen magnum.

Bregma.—The point of junction of the coronal and sagittal sutures.

Dacryon.—The point of junction of the lachrymo-maxillary, fronto-maxillary and fronto-lachrymal sutures.

Glabella.—A point midway between the two supraorbital ridges.

Gonion.—Point of the angle formed by the ascending branch with the body of the lower jaw.

Gnathion.—See Menton.

Inion.—The most prominent point of the external occipital protuberance. (Now of secondary importance. In some specimens the protuberance may be absent; rarely it may be double with a depression between; and in instances it may be wholly replaced by a depression.)

Lambda.—The meeting point of the sagittal and lambdoid sutures. (Often displaced by Wormian or other intercalated bones.)

Maximum Occipital Point.—The point on the squamous part of the occipital most distant from the glabella.

Menton ("Point mentonniére," "Gnathion").—The lowest point in the middle of the bony chin.

Nasion.—The median point of the naso-frontal suture.

Obelion.—A point on the sagittal suture on a line with the parietal foramina. (When both foramina are absent, the point may be estimated by comparison with other skulls.)

Ophryon.—The central point of the smallest transverse diameter of the forehead, measured from on temporal line to the other. (Obsolete.)

Opisthion.—The middle of the posterior margin of the foramen magnum.

Pogonion.—The most prominent point of the bony chin.

Pterion.—The spheno-parietal (or fronto-temporal, when that form exists) articulation.

Subnasal Points.—The lowest point, on each side, on the lower border of the nasal aperture, *i. e.*, the lowest points anteriorly of the two nasal fossae. (If simian gutters are present, the subnasal points may be located on the lines limiting anteriorly the floor of the nasal cavity, or their location may be impossible.)

Stephanion.—The point where the coronal suture crosses the temporal line. (Obsolete.)

Vertex.—The summit of the cranial vault.

Methods.

As with measurements on the living, so with the skull and the rest of the skeleton, our foremost and most binding authority are the International Agreements (q. v., p. 50 et seq.). But as in that case so here the directions may in places be amplified so as to aid the student and prevent misconceptions. More or less obsolete measurements, on the other hand, may well be excluded, for the object of this treatise is to deal with the essential parts, rather than with the entire large field, of anthropometry.

THE VAULT

Maximum length: The maximum glabello-occipital diameter of the vault. Instrument: *c.e.*,[1] any pattern.

Method: As specified by International Agreements (p. 14) and on the living (p. 68).

Maximum breadth: The greatest transverse diameter of the vault above the mastoids and roots of zygomae. Instrument: *c. e.*

Method: As specified by I. A. (p. 14) and on living (p. 69).

Basion-bregma height.—c. e.

Method: Place left forefinger in foramen magnum, press ball of finger lightly against anterior border of the foramen, apply one point of compass so that it rests on the lowermost point of the border in the middle and against the finger, apply other point to bregma, and read measurement. Or, apply point of right branch of compass to bregma and bring point of left branch to basion.

Remark.—The maximum height of the vault is less desirable than the basio-bregmatic, because used by fewer observers, and on account of the not infrequent thickening and ridging of the bone in the sagittal region.

Thickness: Thickness of left parietal, 1 cm. above and along the squamous suture.—*c. e.*

Method: Introduce one branch of compass into the cranial cavity, apply to anterior part of the lower portion of the parietal approximately 1 cm. above the squamous suture, bring other branch in contact with the bone externally, and pass backwards at about the same distance from the sutures, watching the scale of the instrument. Record observed minimum and maximum. These give a mean which is useful for comparison, and which must be taken account of in estimates of skull capacity from external dimensions.

Minimum frontal diameter.—c. e. or *c. g.* Landmarks and method as given by the I. A. (p. 16).

Capacity.—This measurement, corresponding closely to the volume of the brain, is one of considerable importance, and as it is also beset with difficulties it demands special attention.

An ideal method of obtaining the capacity would be by some liquid, water or mercury, which could be easily and directly measured; but attempts at such a procedure have met thus far with unsurmounted difficulties due to the porosity of the bones, the numerous canals and foramina, and the sharp processes on the inside of the skull.

[1] Compas d'épaisseur.

The various older methods of measuring cranial capacity may be segregated into five groups, namely:

1. The skull is made impermeable and after that filled with some liquid, preferably water, which is then weighed or measured; or the water is forced into a thin rubber bag until it fills with this the entire skull cavity, after which the liquid is measured. These methods, employed by Broca, Schmidt, Matthews, etc., yield good results, but are too complicated or tedious for ordinary use.

2. The skull is filled with sand or other substances, and this is weighed, the result giving a basis for calculating the capacity. This method, used especially by some American anthropologists of the last century, was not sufficiently accurate, and soon became obsolete.

3. The skull is filled with small, rounded seeds, beads, shot or other substances, and the contents are then measured (Tiedemann, Busk, Flower, etc.). The filling or the measuring (or both) is aided by certain manipulations (tilting, tapping, etc.), but, except the measuring vessels, no implements are required. The method in its numerous modifications is comparatively easy and has other advantages, but the results are mostly not as accurate as desirable.

4. The method invented and regulated by and named after Broca. In this procedure the skull is packed with shot, which is then measured; but both the filling and measuring are aided by certain implements, and every step of the procedure follows definite rules. Among the implements used appears a funnel of certain dimensions, which controls the flow of the shot. The method gives steady results, but can not be used with frail skulls, and the capacity obtained is always larger than actual, the proportion growing with the size of the skull.

5. Welcker's method.[1] In this procedure, which is the outgrowth of the majority of those mentioned, but more directly of that of Broca, the most important part is delegated to the funnel, which, by its size, controls the measuring of the contents of the skull. The mode of filling the skull, so long as efficient and uniform, is immaterial; all that is required is that each worker should, with the aid of a standard skull, find the exact size of the funnel necessary to give him, in measuring, the correct result with his particular method and substance used for the filling of the skull. Any rounded seed or substance can be em-

[1] *Arch. f. Anthrop.*, Bd. XVI, S. 1 et seq. E. Schmidt, "Anthropologische Methoden," pp. 217–219. A modification of the instruments with a form of a funnel stopper has been proposed independently of the author by E. Landau, *Intern. Centralbl. f. Anthrop.*, etc., 1903, I, pp. 3–7.

ployed for the filling, as it is possible to completely fill the cranial cavity without using the process of jamming, such as that used by Broca; this allows the most fragile skull to be measured without any injury. Welcker advocated a funnel large enough to receive all the contents of the skull. The contents of the properly filled skull are emptied into a separate vessel and then "with one movement is versed into the funnel," which is open (not provided with any stopper) and held in position vertically and centrally above the graduated receiving vessel. Each new series of measurements is controlled by the standard skull.

The author's method, in use since 1901,[1] is a modification of Welcker's. It is based on the observations, that: (*a*) The same substance poured through the same funnel with the same rapidity will always give the same, but with different rapidity will give differing, measures; (*b*) each different substance that can be utilized for the measurement of cranial capacity, flowing through a definite size of funnel and with regulated rapidity, will give different results from those given by any other substance flowing through the same funnel and with equally regulated rapidity. (*c*) Given the same regulation of rapidity of the flow, there can be obtained, through the proper selection of funnels of different diameter, any measurement, ranging between the minimum and maximum of a substance of medium weight and size, by all the solid substances employable for filling the cranial cavity.

Efficient regulation of the flow of the substance used was obtained by adding to the funnel a movable stopper. By doing this, it becomes immaterial as to with what rapidity, or in what manner, the funnel is filled before opening the stopper. This removes at once all source of error connected with the emptying of the cranial contents, and allows us to dispense with the extra vessel used in measuring the cranial contents in Welcker's procedure. With the funnel closed, the cranial contents are poured into it entirely at the convenience of the measurer.

The apparatus used is shown in Fig. 17. The mode of filling the skull is that used by Flower. To measure the contents, they are emptied directly, in any way desired, into a combination of a zinc vessel (higher than, but otherwise similar to, the standard Broca's double liter) and a removable funnel of 45° dip, with 15 mm. high vertical section, which, for my purpose (using old, dry mustard seed) is 20 mm. in diameter. Immediately below the funnel is a movable disk which acts as its stopper. The disk is attached to a rod which rises along the side of the vessel and above its border, and ends in a lever; by using

[1] Described in *Science*, 1903, 1011–14.
Published originally in *Science*, 1903, 1011.

this lever the disk closes or opens the funnel. A number of extra funnels, of the same dip but of different sizes, are provided, from which to choose if another substance than mustard seed is used for the filling. The vessel with the cranial contents is placed on the top of a 2,000-c.c. graduated glass tube (such as used by Ranke), which is fixed in a vertical position. The zinc vessel is provided with a groove in its bottom which

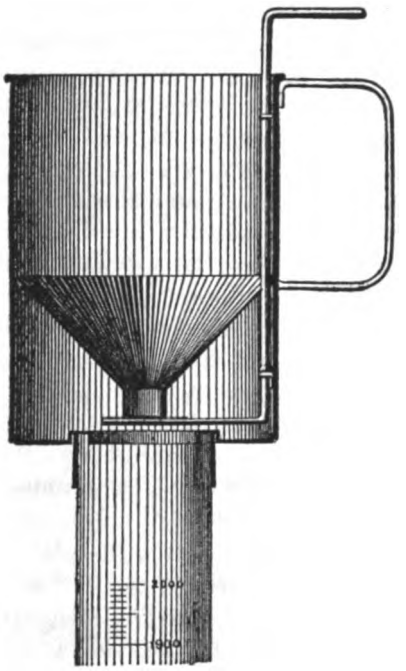

FIG. 17. Hrdlička's apparatus for measuring cranial capacity.

exactly fits the border of the glass, the opening of the funnel being central. Then the lever is rapidly pushed to either side, opening the funnel at once and completely, and the flow left to itself; the level which the seed reaches (determined simply by the eye or, preferably, the careful aid, without any shocks or pressure, of a niveau finder, such as comes with Ranke's tube) is the skull capacity. The measuring part of the capacity determination is thus reduced to a mechanical procedure, which not only makes it easy, but eliminates from it practically all source of error due to personal equation. What the student needs to learn is some method by which a complete and uniform filling of the skull can be effected, and then, working with the aid of standard

skulls, choose the proper funnel; the rest is controlled. The results, always with the condition that the proper use is made of the standard skulls, are as uniform and as near the reality as can be reasonably hoped for.[1]

FACE

Menton-nasion height (or "*nasion-menton diameter*").—*C. e.*, or *c. g.*

The distance from menton to nasion, with the lower jaw in place and the teeth in apposition. Note condition of teeth, especially as to wear.[2]

Alveolar point—nasion height (or "*naso-alveolar diameter*").—*C. g.*, or *c. e.*

Landmarks.—See I. A. (p. 16).

Maximum bizygomatic diameter.—*C. e.*, or *c. g.*

Landmarks, etc.—See I. A. (p. 16).

BASE

Basio-alveolar diameter.—*C. e.* or *c. g.*

Distance between basion and the alveolar point.

Basion-subnasal point diameter.—*C. e.*

Distance between basion and the left subnasal point.

The triangle basion-alveolar point—subnasal point-basion gives the measure of alveolar prognathism, which it is useful to show separately from the facial prognathism.

Basion-nasion.—*C. e.*

Distance between basion and nasion. The angle between the basion-alveolar point line and that from the alveolar point to nasion, gives the facial angle, which is the expression of the combined alveolar and facial prognathism.

NOSE

Nasal height.—*C. g.*

Landmarks: As given by I. A. (p. 16)

Method: Measure to base of spine, or separately to each subnasal point and record the mean.

Nasal breadth.—*C.g.*

Landmarks and *Method:* As given by I. A. (p. 17).

[1] The apparatus is not made for the market, but it should not be difficult for any one to have it constructed by following the given directions.

[2] The question as to whether to allow for the wear of the teeth, when this is present, or not, has not as yet been decided. Until a definite international rule is established, it seems best to record both the actual measurement, and an estimate of what the latter would be with teeth in normal condition.

Orbits

Orbital breadth.—C. g.

Landmarks and *Method:* As given by I. A. (p. 17).

Orbital height.—C. g.

Landmarks and *Method:* As given by I. A. (p. 17).

Upper Alveolar Process ("Palate")

Breadth.—C. g.

Length.—C. g.

Landmarks and Methods: Follow I. A. (pp. 17, 18).

Lower Jaw

Bigoniac breadth.—C. g.

The diameter between the most distal points on the external surface of the angles of the jaw.

Method: Use stub branches of the compass. Apply instrument so that the rod rests on each side against the ramus ascendens, while the branches are brought to the most prominent points about the angles of the jaw.

Angle of lower jaw.—Broca's mandibular goniometer.

Method: See I. A. (p. 21).

Note: The angle differs in general on the two sides of the jaw. The logical procedure is to measure the angle on both sides and record the mean.

Height of symphysis.—C. g.

Height of the body of the lower jaw.—C. g.

Maximum thickness of the body of the lower jaw.—C. g.

Landmarks and Method: As given by the I. A. (p. 20).

Note: To obtain the thickness, measure same on both sides and record the mean (if marked difference is found, individual measurements may also be given). The instrument should be held so that the midline of the teeth (antero-posteriorly) corresponds to the midpoint of the rod of the compass between the two branches.

Miscellaneous

Maximum Circumference.—A. t.

Landmarks and Method: As given by the I. A. (p. 19).

Sagittal arc.—A. t.

Landmarks and Method: As given by the I. A. (p. 18).

As a rule no single character of a skeleton, skull or a bone should be relied upon in sex differentiation, unless so developed as to be beyond the range of its variability in one of the sexes.

A proportion of specimens that an experienced and careful observer will have little or no difficulty in correctly identifying as to sex, is over 80 per cent of the adult crania with which there is neither the lower jaw, nor any other part of the skeleton, to assist him; this proportion will approximate 90 per cent where a well-preserved lower jaw is present; and it will reach 96–98 per cent where there is the whole skeleton. But out of each hundred there will still remain two to four skeletons which, even though complete, show such indefinite sexual characteristics that it will be impossible to identify them by any expert, as either male or female, with certainty.

Sex Identification of the Skull. Given a skull for sex identification, the observer notes first the size of the vault, as well as that of the face—a large size of one or both will speak normally for a male, a smaller size suggesting a female. The features observed next, in the order named, are the supraorbital ridges, the mastoids, the occipital and temporal crests, the zygomae, the malar bones, the alveolar arches and teeth, the lower jaw, the palate, the base of the skull, and the facial "physiognomy."

The *supraorbital ridges* on the average are decidedly more developed in the males than in the females. If we should characterize them, as we do in practice, by the term "traces," "slight," "moderate," "medium," "pronounced," and "excessive," the male skulls will show ridges from moderate to excessive, while the female skulls will be restricted to those of from traces to moderate. Pronounced or excessive ridges do not occur in recent females, nor are ridges that could be characterized as only "traces" to be found in adult males. We may however have but "slight" ridges in a male subadult or even adult. The African and American Negroes, and the more highly cultured Whites, show numerous such instances.

The *mastoids* may be "small," "moderate," "medium," "large," or "excessive." Male mastoids generally range from medium to large, female mastoids from small to medium. Small mastoids do not occur in males, nor do large or excessive mastoids occur in females. But in individual females of especially strong muscular development the mastoid processes may reach a size corresponding to the "moderate," or near medium, male.

The *occipital crests* when well or markedly developed as a rule indicate a male. In females they range from "submedium" to "absent." In general, it may be said that the more marked the muscular ridges and depressions on the occiput and the rest of the vault of the skull, the more likely it is that of a male; and vice versa.

The *supramastoid* and *temporal crests* and roughnesses are, when markedly developed, as a rule male, smoothness of the parieties and the rest of the vault speak for a female.

The *zygomae* may be "slender," "moderate," "medium," "strong," or "heavy." They range in males from medium to heavy, in females from slender to near medium. They are generally also broader in the males.

The *malars* are better sexual marks than is generally appreciated. On the whole, in the male they are high and stouter, in the female low and more delicate. In both sexes, of course, there are some intermediary conditions. The height of the bone is its diameter at middle from the orbital border downward.

The *alveolar arches* tend in the male to be very appreciably higher, in the female to be lower than the general average. As sex determinants, these characters are of equal value with those of the malars. The arches may also differ more or less in the two sexes in strength, being weaker in the female, but this distinction loses much of its weight in primitive peoples, and particularly in the Eskimo and the more northern (as well as other) Indian tribes. But the jaws in the women of these groups have been used relatively more than they are in civilized people.

The *teeth* are not very good criteria for sex differentiation. On the whole the female teeth tend to be slightly to moderately smaller in all dimensions, but there are numerous exceptions to this both in primitive and in civilized peoples. Exceptionally high canines ("dog-teeth"), however, seem to occur occasionally in males only.

The *lower jaw* in the male shows on the average greater size, thickness, and weight as a whole, a higher body throughout, a higher symphysis especially, a broader ascending branch, an angle less obtuse than in the female, stouter and rougher gonion regions, and strong condyles. A lower jaw of moderate size and strength, with a low symphysis and body, a rounded or pointed and smooth chin, only moderately broad ascending ramus, delicate or but moderately strong condyles, smooth gonion regions, and an angle of more than 125°, may safely be diagnosed as feminine. No great weight, however, should be placed in the sexing of a lower jaw either on the angle, or the breadth of the ramus, for there is a considerable overlapping in these features in the two sexes. A square chin points strongly to male sex, but is not wholly unknown in the females. Markedly everted angles are as a rule masculine.

The *palate* in the male skull is usually larger, broader, and normally relatively less high than in the female.

The *base* of the skull in a well-developed male is stronger and more sculptured or rough, in the female it tends to be flatter and somewhat more delicate. It is justified to speak of a "male base" and

a "female base." The pterygoid, styloid and the spinous processes are never very strongly developed in the female, and the glenoid cavity in the female skull is usually less spacious than that in the male. The condyles are larger and stronger in the male, the styloids stouter, and all the rest of the parts of the base tend to be more strongly developed and to be larger or grosser in the male than in the female. But in all these features there is some interdigitation between the two sexes.

The "*physiognomy*" of the face, or the total impression that the face, especially with the lower jaw in position, makes upon the experienced observer, is a complex unit of considerable importance in sex determination. The average male skull presents a decidedly more masculine physiognomy than does the average female cranium. This is due to a combination of factors which should be briefly enumerated. The forehead in the female skull is usually more vertical than in the male, and smoother; the borders of the orbits in the average male skull are dull, in the average female sharp; the nasal process of the frontal, the nasal bones, the malars, and the upper maxillae, as a whole, are larger and stouter in the male than in the female; and the height of the upper alveolar process, between the nasal aperture and the front teeth, is greater in the male. The nasal aperture is less high, often relatively somewhat broader, and more delicately moulded in the female, the teeth in the female skull are often appreciably smaller. All this, together with the sexual characteristics of the lower jaw, when present, gives the face a certain expression which is of great help in identifying the sex of the skull. Unfortunately the lower jaw is often missing, and the upper face damaged or affected by senile changes, all of which diminishes or disturbs the sexual expression.

Skull capacity is a highly useful item in the sexing of skulls. Due mainly to a greater stature and basic bulk the male has a larger brain and hence larger cranial capacity than the female. The average difference between the two, in any given group, ranges from 150 to 200 cc. The female capacity in addition only seldom reaches above 1500 cc., while in the males, especially in some human aggregates, such occurrences are common. In general a capacity of above 1450 cc. suggests a male, capacity of 1300 cc. or less suggests a female. There are exceptions, but they rapidly grow rarer as one proceeds either above or below these figures.

Regardless, however, of its actual magnitude, cranial capacity in many a doubtful case of sexing may play a determining part. This is through its correlation with the external dimensions of the skull. The matter has been found and determined by the writer. It consists of the fact that if the cephalic module, i.e., the mean of the length, breadth and height of the vault, is taken and expressed in four

figures, these figures in the male skull are generally close to the capacity of that skull given in cubic centimeters, while in the female the capacity is generally from 150 to 200 points lower than the four-figure mean diameter. In other words in a male skull, whose mean diameter in four figures would be say 1500 (15.00 cm.), the capacity will generally be fairly close to 1500 cc.; while in a female skull of the same mean external diameter of the vault the capacity of the skull would in all probability range only between 1300 and 1350 cc. The causes of this important difference lie in the differences of the internal conformation of the cranial cavity in the two sexes. The rule, as some years of experience has shown, has a few exceptions, and occasionally the difference between the two figures is not sufficiently pronounced; but in many cases the results are very definite and deciding, so long as we deal with skulls of medium proportions. In very small or very large skulls the rule is not reliable.[1]

Sex Characteristics of Other Skeletal Parts. As in the sex identification of the skull, the student is often obliged to consult the rest of the skeleton, if at hand; and on occasions the skull may be missing, or there may only be preserved isolated bones or even but parts of a bone or bones, and yet it be of importance to identify the sex of the remains. The principal sex determining characteristics of the bones may well therefore be dealt with in this connection.

In detailed examinations it is found that nearly every bone in the body offers sex differences. The most important skeletal parts for sex identification aside from the skull are, however, the pelvis, the long bones, and the larger remaining parts.

As to the *pelvis*,[2] the important sexual characteristics which it presents may conveniently be shown as follows:

[1] See author's "Normal Micro- and Macrocephaly," *Am. J. Phys. Anthrop.*, 1939, XXV, no. 1.

[2] See (besides the modern textbooks on Anatomy, and Obstetrics):

Emmons (A. B.), "A study of the variations in the female pelvis," etc., *Biometrica*, 1912, IX, 33–37.

Hennig (C.), "Das Rassenbecken," *Arch. f. Anthrop.*, 1885, XVI, 161–228 (Bibl.).

Pachner (P.), "The sex differences in the human pelvis," Prague, 1937, 83 pp. Publ. by the Czech. Akad. Sci's & Arts).

Runge (G.), "Shape of female pelvis in different races," 8°, St. Petersburg, 1888; 80 pp.

Sergi (G.), "L'indice ilio-pelvico o indice sessuale nel bacino delle raze umane," *La Clin. Ost.*, 1899, I; 7 pp.

Thompson (A.), "The sexual differences of the foetal pelvis," *J. Anat. and Physiol.*, Lond., 1899, XXXIII, 359–380.

Verneau (R.), "Le bassin dans les sexes et dans les races," 8°, Paris, 1875, 156 pp.

Waldeyer (W.), "Das Becken." 8°, Bonn, 1899, 600 pp.

Zaaijer (T.), "Der Sulcus preauricularis ossis ilei," *Verh. k. Akad. Wet.*, Amsterdam, 1893, 23 pp.

	Male	*Female*
Subpubic arch	V-shaped	Broader (approaching U-shaped) with diverging branches
Ischio-pubic rami	But slightly everted	Markedly and characteristically everted
Symphisis	High	Lower
Obturator foramina	Large	Smaller, more triangular
Acetabula	Large	Smaller
Greater sciatic notch	Rather close and deep	Wide and shallower
Ilia	High, more upright	Lower, more flaring in upper portion
Sacro-iliac articulations	Large	Smaller, more oblique
Preauricular sulcus	Infrequent	More common and better developed
Sacrum	Relatively high and narrow; may have more than 5 segments	Shorter and broader, more obliquely set, less curved in upper portion; sacro-vertebral angle more prominent; has as a rule but 5 segments
Pelvis as a whole	Strong, heavy, marked muscular impressions	Less massive, smoother
Brim	Heart-shaped	More circular (or elliptic), more spacious
True pelvis	Relatively smaller	More oblique, shallow and spacious, less encroached upon by ischiac spines

None of the above characteristics are, of course, wholly constant, and there are pelves so intermediate that a correct diagnosis of sex from them alone cannot be made with confidence. But there are many pelves or even fragments of pelves, if from the right place, which even unaided may be identified as to sex with practically absolute certainty. The feature which permits this is the greater sciatic notch. A narrow notch marks invariably a male, broad one a female. There are intermediary forms, but they are not very frequent. The character is so valuable that no other sex determinant on the skull or skeleton exceeds it. It is the first to look to in all doubtful cases.

As to the *long bones*, those of the male are generally larger and heavier than those of the female and have more pronounced muscular ridges, crests, tuberosities and impressions; but the most important and constant sexual differences lie in their articular extremities, which in the bones of the male are in general both absolutely and relatively

larger than in the female. A femur or a humerus with a relatively small head or condyles cannot be masculine, neither can bones with relatively large heads or condyles be feminine. These differences are of great help in sexing the skeleton or individual bones. However there are also here intermediary grades of development which might leave the student uncertain if he had the long bone or bones only.[1]

As to the remaining larger bones of the body, the most important for sexual identification are the sternum, scapulae, ribs, the spine as a whole, some of the individual vertebrae such as the atlas, axis, and the fifth lumbar, the patella, the calcaneus and talus and the phalanges, especially the proximal phalanx of the great toe. In general they all show larger size, greater weight and stronger development of muscular attachments in the male; and they present various individual features which differ more or less in the two sexes, such as the relatively longer manubrium in the female, a larger glenoid cavity in the scapula in the male, etc. Their utilization for sexual identification stipulates naturally a special thorough acquaintance with these various bones.

Even the smaller bones of the tarsus, the clavicle, the ribs, and other bones not yet mentioned, may help in sex identification; but the main reliance, except in cases of pronounced development one way or the other, must be placed on the parts mentioned previously.

In addition to the differences due to the general development of bones, various parts of the skeleton occasionally present special features, as for example a perforation in the septum in the humerus, third condyle on the femur, a teres major process of the scapula, etc., which do not occur with the same frequency in the males as in the females; but as they may occur in both, their presence or absence in individual cases is of but little value. Furthermore, all the bones of the skeleton when studied in lots will show characteristic sexual differences of anthropometric nature, in absolute dimensions as well as indices; but except in extremes these again are of only secondary value in the case of the individual bones.[2]

[1] Consult Dwight (Thos.), "Range and Significance of Variation in the human skeleton," *Bost. Med. and Surg. J.*, July, 1894, 73 et seq.—"The size of the articular surfaces of the long bones as characteristic of sex," *Am. J. Anat.*, 1904, IV, 19–31.

Dorsey (Geo. A.), "A sexual study of the size of the articular surfaces of the long bones in aboriginal American skeletons," *Bost. Med. and Surg. J.*, July 22, 1897.

[2] See author's "Physical Anthropology of the Lenape," etc., Bull. 62, Bur. Am. Ethnol., Wash., 1916.