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IROQUOIS SILVERWORK,

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ILLUSTRATIONS.

PLATES.

Text Figures.

IROQUOIS SILVERWORK.

The art of the silversmith among the Iroquois seems to have had its birth along toward the end of the seventeenth century, when, according to Beauchamp,[1] historical records show that silver ornaments of Indian make were first noticed by Europeans. These ornaments had apparently displaced in part those of copper and brass, which, although quite different in character, had been popular among the people. The brooches, rings, and bands of silver, Beauchamp continues, remained in vogue until the latter half of the nineteenth century, when they gradually gave way to the cheap jewelry of the whites. To-day it is rare to see native ornaments used even in the Long House ceremonies of the so-called Pagan Iroquois.

Morgan[2] and Beauchamp[3] devote but very few lines to the manufacture of silver ornaments, and merely mention some of the tools used. Knowing this, I have always been on the lookout, during my visits among the Indians, for a surviving Iroquois silversmith; but it was not until January, 1907, that my search was successful. At that time I was engaged in collecting ethnological material, on the Six Nations Reserve in Ontario, Canada, for the American Museum of Natural History. Repeated inquiries for silversmiths and their outfits of tools led at last, after several failures, and many investigations of false reports, to the discovery of an ex-silversmith in the person of Chief Levi Joe (an Onondaga), and of a nearly complete outfit of tools, once the property of his grandfather. Chief Joe is not an old man; but his vision has become defective, and he has been obliged to give up his calling. After several interviews I succeeded in buying the box of tools and in obtaining the Indian names of each piece, besides observing several of the processes, and taking a few photographs. Later the chief explained to me as much as occurred to him concerning the details of silversmithing, and made working models of several articles once belonging to the outfit, but now lost. As all his old patterns were missing, he made some new but rather poor ones, and at my request prepared for me two unfinished brooches to illustrate stages in the process of manufacture. Some months later a second visit was made, and more specimens and information were secured.

[1] Beauchamp, Metallic Ornaments of the New York Indians, p. 10.
[2] Morgan, League of the Iroquois, new edition, Vol. II, p. 50.
[3] Beauchamp, Metallic Ornaments of the New York Indians, p. 36.

Before taking up in detail the description of Chief Joe's outfit and method of work, I will endeavor to discuss briefly the principal classes of native-made silver ornaments still found among the Iroquois. As a number of writers, including Mrs. Converse [1] and Beauchamp,[2] have given us careful descriptions of their many varying forms, it will only be necessary here to set forth a few representative types.

Most numerous of all are the brooches which may still be found occasionally in the hands of the Indians. Those, as may be seen in the figure, are flat silver disks of different sizes, ranging from about a fourth of an inch to six inches in diameter, cut into many artistic forms, and often engraved, stamped, and embossed as well. Each has a central opening, crossed by a tongue (like that of a buckle) pivoted at one end, which serves to attach it to the fabric. Six principal patterns may be recognized, which I have called: 1. Simple disk; 2. Ornate disk; 3. Star; 4. Heart; 5. Square; and 6. Masonic.

The first is merely a simple, very narrow circlet of silver, usually convex above and concave beneath, with a large central opening (Plate XXIII, Fig. 1). Sometimes the narrow circlet is solid instead of hollow, in which case it is sometimes decorated (Plate XXIII, Fig. 2).

The ornate disk is quite distinct from this, as the central opening is as small as possible, and the resulting broad surface of the silver, or field, is highly decorated with engraving, embossing, and openwork (Plate XXIII, Figs. 7, 8, 9). The star is similar to the ornate disk in having a small central opening; but in this case the silver field is cut into rays of varying number, forming a star-shaped figure. Each ray is tipped with a circular boss, which lends a pleasing and characteristic effect to the whole (Plate XXIII, Figs. 13, 14). The heart-shaped brooches are among the commonest forms. They generally consist of two overlapping heart-shaped figures surmounted by a device which sometimes resembles a crown, and sometimes an owl's head. The hearts are outlined by a narrow band of silver, the tongue passing across the resulting central opening; while the broader surface of the crown affords a field for engraving and openwork. A variant of this pattern represents a single heart only, with or without the characteristic crown or owl's head above (Plate XXIII, Figs. 3, 4, 5). The term "square" is rather a misnomer for the fifth type of brooch; for the two concentric figures which make the characteristic form are squares only by virtue of having four equidistant corners, the four equal sides being concave instead of straight (Plate XXIII, Fig. 10). The corners even are so blunt, as a rule, that the type might be called "octagonal." Like the heart-type, the squares are outlined with

[1] Converse, H. M., The Iroquois Silver Brooches (54th Report New York State Museum).
[2] Beauchamp, Metallic Ornaments of the New York Indians, pp. 74–94.

narrow strips of silver just wide enough to bear a little engraving, and consequently they have a broad central opening across which the tongue passes from corner to corner. Single squares occur (Plate XXIII, Fig. 11), and these like the majority of the simple disk-type, are sometimes concave beneath.

The Masonic type is merely the familiar square and compasses, sometimes conventionalized and ornamented (like the specimen shown in Plate XXIII, Fig. 15), almost beyond recognition. I may say here that most Indians do not recognize the significance of this pattern, but use it simply as an ornament.

Specimens of all the principal types of brooches are figured in this paper; but, as the many variations and aberrant forms are carefully discussed in the works above referred to, it is not necessary to take them up in detail. It is sufficient to say that the variations are effected by the different forms and sizes of the apertures and notches cut into the metal, by bosses raised at various places (notably at the ends of the rays of the star-form and around the circumference of the disks), and by the different varieties of engraving. I have seen dots, straight lines, curved lines, fine zigzags, tiny triangles, and other figures in many combinations. Life forms are very rare.

Chief Joe had names for a number of the patterns. The simple disks he called o-ga′-hä, which signifies "eye." The ornate-disk and star types he grouped together under the name de-yo-dĕ^{n}-hai′ĕ^{n}-da', interpreted as "sunshine." The crowned heart brooches, double and single, were similarly grouped as o-gō″-ji-a, meaning "ornamental head-dress or crown;" while the single heart-form was known as a-wē′-ya-'sa' or "heart." The double-square type he named de-yo-ä^{n}-wa-gĭs′-ho^{n}, translated as "double brooch;" the single-square form being jo-ä^{n}-wa-das′-ho^{n} (de-yo-ä^{n}-wa-das-ho^{n}?) or "single brooch." When shown a Masonic brooch of pure type, the chief told me he knew no name for that variety; but the more common conventionalized Masonic design (the kind shown in Plate XXIII, Fig. 15) he readily recognized under the name ga-ya′′-sa^{a}, "cross" or "crucifix," so called, he said, on account of the fact that it usually bears from two to five engraved conventional crosses. This type originated with Christian Indians, he informed me.

The only trace of true symbolism was found when the chief was questioned concerning the heart-type of brooches. He stated that the intertwined hearts surmounted by a crown represent the Iroquois nations united in friendship, and that these brooches were formerly considered a sort of badge or emblem identifying the wearer, man or woman, as an Iroquois. Chief John A. Gibson told me practically the same thing. The only outside evidence to support this idea lies in the fact that brooches of the crowned double-heart variety are rarely, so far as I know, found outside of the Iroquois Six Nations. Mrs. Converse,[1] offers interpretations for many forms, and I refer the reader to her pamphlet. As there is usually a great deal of variation in statements by Indians concerning symbolism, more data should be collected; for, notwithstanding all these differences, some underlying concepts may be discoverable.

Brooches were employed for many decorative purposes, as the ornamentation of women's dresses, where they were sometimes used in great profusion, and for decorating the ribbons, head-bands, and sashes used by both sexes. I have seen them fastened also upon the wide band of broadcloth used to wrap about the infant on the cradle-board. It will be noticed that all these uses require attachment to some fabric, which was effected as follows, — a portion of the cloth was bunched together and forced up through the central opening of the brooch far enough for the tongue to be pushed through it, then, when the fabric was pulled flat again, the ornament was firmly attached. The process is shown in Fig. 1.

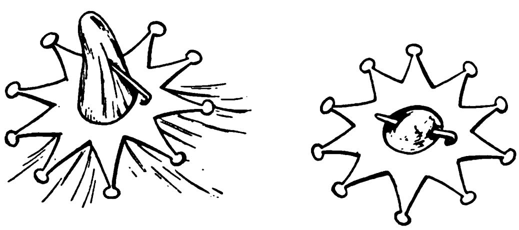


Fig. 1. Method of fastening Brooches.

Brooches are generally called ĕn-yŭ″-skä' in Seneca, and dĕ^{n}-ha-nīs-ta' or a-da-ha-nīs′-ta' in Onondaga. Beauchamp gives ah-ten-ha-ne-sah as an Onondaga name for them, but this probably is a variation of the above. The Cayugas often call them an-ya′-ska; the Oneida, a'-nyu'-ska-līst; and the Mohawk, an-yŭ″-'ska-re. It must be understood that in all these languages there are probably several words that can be applied to each article.

Next in point of numbers to the brooches are the ear-rings, formerly widely used by both sexes, but now usually confined to a few women. The men, when wearing ear-rings at all, now generally prefer the small, plain gold hoops made by the whites. Ear-rings of native manufacture may be divided into two classes. The first type and the commonest form (Plate XXIII, Figs. 18, 19) consists of a drop, or body to the flat back of which is soldered the hinged wire passing through the ear, as shown in Fig. 2. This

[1] Converse, H. M., The Iroquois Silver Brooches (54th Report New York State Museum).

drop may be a small hemisphere, called "chestnut" by the Indians (Plate XXIII, Fig. 19), or may be large, flat, and decorated with openwork and engraving like a brooch. Sometimes it is cut into the form of a spread eagle, hawk, or other bird (Plate XXIII, Fig. 16), and sometimes has a setting of colored glass (Plate XXIII, Fig. 18). Removable pendants often hang from these drops attached to the ear-loop, usually pear-shaped, but occasionally of other forms. Now and then they are also set with colored glass, and sometimes strings of hollow silver beads are used as pendants. Another form is shown in Plate XXIII, Fig. 20. The second type embraces the plain silver hoops (Plate XXIII, Fig. 21), which are rare, and the flattened hoops or crescents, which I have heard called "half-sun" ear-rings. Common words for ear-rings are a‘-wŭs′-hä in Seneca, ga‘-was′-ha in Cayuga, ka-wa′-ṣa in Onondaga, ka-was′-ha in Oneida, and de-a-ga-wa′-sa-re in Mohawk. This last word, I suspect, means a "pair of ear-rings," as the prefix "de-" often expresses duality in Iroquois languages.

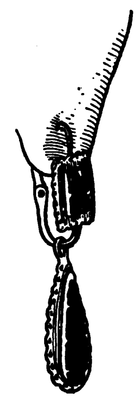


Fig. 2. Method of fastening Ear-Rings.

Finger-rings were also of silver, either plain, or decorated with hearts or other devices engraved upon a part of the circlet made broader for the purpose, or upon a separate piece soldered upon the band, the whole having a seal-ring effect (Plate XXIII, Figs. 23, 24, 25, 26). In Cayuga, rings are called e^{n}-n‘ia′-ha-shra′; by the Oneida, ha-ni-sno^{n}-so-lok′-ta; and by the Mohawk, a-nis-nu^{n}′-sa-wi.

Bracelets and armlets were broad bands of silver, usually quite thin and pliable, with holes in the end for fastening with cords. The pair in the Museum, however, are rather thick and stiff, like the Navajo bracelets, and consequently need no holes (Plate XXIV). They are also engraved, while the usual Iroquois bracelet is fluted. They are worn with ceremonial dress.

Of similar character, although larger and more ornate, are the head-bands or crowns of silver, often about two inches wide, which frequently show elaborate and tasteful combinations of fluting, engraving, embossing, and openwork. These are now very rare, but are still occasionally used as part of the ceremonial head-dress, as shown in Plate XXIV. Morgan[1] illustrates globular silver beads used with wampum as a necklace, and I have sometimes heard of double and foliated silver crosses made by the Indian silversmiths, and used as ornaments. Chief Joe, without any suggestion on my part, made for me a tin pattern for a double cross to go with

[1] Morgan, The League of the Iroquois, new edition, Vol. I, p. 254.

the rest of his outfit of tools. There is also a variety of silver ornament which I have never seen described, the silver nose-ring. The only specimens of this that I have seen were in the possession of King Tandy Jimerson, a Seneca of the Alleghany Reservation in western New York. There were two, I believe, of crescent-shape, the tips of the crescent approaching each other in such a way that the ornament could be pinched fast upon the septum of the nose. At least one of the specimens seemed old, but I doubt if the style was widely distributed.

We will now turn to a description of the tools with which these things were made, so far as they are represented by the contents of the battered tin box which Chief Joe found for me in the loft of his little cabin on the banks of the Grand River. The Indian names here given for the tools, as mentioned before, are probably not the only ones that could be applied to them, and it is possible that errors have crept in through imperfect interpretation. It is unfortunate that time would not permit my working out the literal meaning of the names themselves. The outfit as a whole is called Ĕ-wĭs-ta-no-wĕⁿ-tsĕⁿ-nia′′-ta', and consisted of the following: —

Anvil, De-ye-da-gwĕⁿ-dĕⁿ-da′′-kwa' (Plate XXVI, Fig. 4). This is naturally one of the most important articles of the outfit. It is a rectangular block of cast-iron, four inches and a half long, two inches wide on the top where the hammering was done, and three inches high. A perforation and some figures on the broadest sides seem to show that it was evidently made by the whites for use as a scale-weight; but the battered top, scarred with the marks of the silversmith's chisel, tells the story of its Indian use.

Hammers, Ga-jī′-kwa (Museum Nos. 50–6692, 50–6796). A large hammer, used to flatten out the silver to proper thickness, is shown in Plate XXVI, Fig. 1. Another specimen, a small one, is for fine cutting and stamping. It consists of a rude head of iron attached to a thin wooden handle, the whole being but little over six inches in length. This is figured in Plate XXV, Fig. 15.

File, Ha-de-geⁿ-tsä′-nīē (Museum No. 50–6694). This is an ordinary three-cornered file bought at some store. The only interest attaching to it is in the fact that the end is worked down to a triangular point, which would do excellent service as a drill or reamer for perforating thin silver (Plate XXV, Fig. 14).

Pincers, Do-was-jī-ē-ta (Museum No. 50–6693). The pincers or pliers, rather rude yet serviceable, are of iron, made apparently by some county blacksmith. The rounded jaws were very useful in bending finger-rings and ear-ring loops (Plate XXV, Fig. 10).

Chisels for curves, Ē-iák′-ta' (Museum Nos. 50–6698, 50–6699). At first there were in the collection only two chisels for cutting along curved lines;

but two more were afterwards found. The first two are made of old jack-knife blades (Plate xxv, Figs. 20, 21). The truncated end of the larger one is filed to an edge like that of a gouge, in the form of a curve. The point of the second is very narrow, but is straight, the curve being produced by a succession of short cuts which were afterwards joined, and the resulting ragged edge filed smooth. Of the second pair found, one is a store-bought gouge, while the other is made of an old carving-fork handle.

Chisels for straight cuts, Dē-ē-iak′-ta' (Museum Nos. 50–6695–6697). There are in the collection, three chisels for cutting along straight lines, the most important of which is also made from an old jack-knife blade, whose battered base tells of long use. Its edge is five-sixteenths of an inch wide. With a longer edge (three-fourths of an inch) is another chisel, originally a cutter for a blacksmith's anvil. The third specimen (a small one, with an edge three-sixteenths of an inch) was actually made for a cold-chisel; but the Indian silversmith has purposely dulled, even squared, its edge, for use in fluting bracelets, head-bands, etc. (Plate xxv, Figs. 8, 9, 19).

Awls, Ē-hak-ta′′-so-a (Museum Nos. 50–6703–6706. Three true awls and an ear-piercing implement were classed together under this name by Chief Joe. The largest is part of an old knife-blade filed down to the form of an awl, whose cross-section would be almost exactly square. Although the blade is hardly three-fourths of an inch long, the hardwood handle is fully four inches and a half long, and nearly three fourths of an inch thick. The second awl is similar in section, but is made of a broken drill-blade, and set in a smaller handle; while the third is a large broken needle similarly mounted, whose end has been sharpened by filing to an angular point (Plate xxv, Figs. 23, 24, 25). The ear-piercing awl is an ordinary needle mounted in a wooden handle like the rest (Plate xxv, Fig. 22).

Gravers, Ē-iá-na'-da'-kwa' (Museum Nos. 50–6700–6702). There are three gravers, all similarly mounted in crude home-made wooden handles. The largest is more like a chisel, having its edge bevelled from one side only, but seems nevertheless to be made of an old knife-blade. The other two have the bevel from both sides, like a drill; but the use of all three is similar, according to their former owner (Plate xxv, Figs. 11, 12, 13).

Die-plates and stamps, E-ji-ni-u-gú^{n}-nia-ta' (Museum Nos. 50–6805 A–B). The die-plate, used mainly for embossing, is a little block of iron about two inches long by an inch wide and a little less than a fourth of an inch thick. On its top surface are four hemispherical concavities of varying size, which served as dies. The largest, for working ear-drops, three-eighths of an inch across; and from this the dies for embossing range down to less than an eighth of an inch in diameter. The edge of the plate is roughly bevelled. For each die there is an appropriate stamp or punch whose convex end fits into the concavity. Little can be said of these punches, except that they show evidences of long use, and, like the die-plate, seem to have been made especially for this purpose by some blacksmith, or perhaps some Indian with a smattering of iron-working knowledge (Plate xxv, Figs. 3, 4, 5, 6, 7). There is also a punch or stamp, the end of which has been filed into a pear-shape to form the pendant cone often used with ear-rings; but the die belonging to it is missing from the set (Plate xxv, Fig. 17). For making hollow simple-disk brooches is the lead die-plate (Plate xxv, Fig. 1) secured on the second trip. This bears a smooth circular groove the size of the future brooch, into which the thin metal is pressed with the aid of the punch (Plate xxv, Fig. 2). This outfit bears the special name O-ga-hē′ gwa'-ĕ'-sä^{n}-nia-ta'.

Cutter, O-ga-hē-gwa'-ē-yak′-tha (Museum No. 50–6801). This is a piece of iron bent into pipe-form and the edge of one end sharpened all around. It is made for cutting out disks of silver for brooches (Plate xxv, Fig. 16).

Spreader, De-ie-da-gwai-da′-kwa' (Museum No. 50–6707). This is a chisel-like implement used especially to spread the split in the wire to make the hinge in the loops of ear-rings. If it were not for its straight chisel-like lines and home-made handle, one might take it for a screw-driver (Plate xxv, Fig. 18).

Lamp, Ē-jīs′-to-da-kwa' (Museum No. 50–6723 A–B). This is merely an old rectangular sardine-can with lid removed and edges rounded. The wick is a twisted bit of rag, which when in use protrudes above the edge at one corner. Almost any inflammable oil or grease seems to have been used. The wick of the present specimen shows traces of having been used with sperm-oil, which of course is modern (Plate xxvi, Fig. 5).

Patterns, De-yo^{n}-de'-ni-ĕ^{n}-dĕ^{n}s′-ta'-kwa' (Museum Nos. 50–6714, 6716). All the old patterns belonging to this collection are unfortunately lost; but Chief Joe made two new objects out of tin; one a crude representation of the star brooch, the other a very fair double cross (Plate xxiii, Figs. 22, 27). Mrs. Converse, in her "Iroquois Silver Brooches," mentions the fact that one silversmith had a collection of patterns made from the zinc back of an old washboard.

Box, Ga-hú^{n}-sä (Museum No. 50–6690). This little tool-chest, resembling a trunk in form, is made of tin, and is provided with a handle and hasp. It is evidently of white man's make. The dimensions are eight inches and a half by five inches and a half by four inches and a half. All the smaller tools, patterns, etc., were kept in this.

Moulds, Ē-jī-sta′-hä-kwa' (Museum Nos. 50-6719–6721). There are three moulds in the collection, one of which, the smallest, has been used. The others are merely models. The term "furnace" might well be applied to them also, for they are used for both melting and casting. The old specimen is made of a rather irregular block of hardwood some five inches square and three inches and a half thick. In one of its broad faces is cut a rectangular hole with converging sides about three inches wide and a little less than an inch deep, leaving a flat area in the middle. In the centre of this the mould proper was neatly cut, about an inch and a half long by half an inch wide and a fourth of an inch deep. Into this melted silver flows. The whole specimen shows the effect of long use, being heavily weathered and charred. The new moulds are larger and not so deep, the larger casting an ingot ten inches long by an inch wide, the smaller about seven inches long (Plate XXVI, Figs. 3, 6).

Blowpipe, U^{n}-wĕ^{n}-da′-sta' (Museum No. 50–6722). This is a model, and is made of a hollow sumach-stick some fourteen inches long and an inch and a fourth thick, with one end cut to form a rude mouthpiece, but without a nozzle (Plate XXVI, Fig. 2).

Poker, Tē-yē-jī-sta-wĕ^{n}-yē′-da'-kwa' (Museum No. 50–6723). This is a wire at the end of, and inserted into, a wooden handle. It was used for raking up the coals on the mould-furnace above described.

Chief Joe mentioned a number of articles as being missing from the collection, of which the most important are the patterns, of which he furnished only two, both models, and poor at that. There should be patterns for every type of brooch and for the different parts of finger-rings and ear-rings. There are also missing the die-plate belonging with the stamp used for making pear-shaped ear-pendants, and probably other articles.

For the sake of comparison and to fill up these gaps, if possible, it was thought best to examine another Iroquois silversmith's outfit. The only other one[1] known to the writer is in the collection of the Montgomery County (New York) Historical Society, who kindly loaned the set to the Museum for study. This outfit, also of Onondaga origin, is very rich in small tools, and contains besides a number of old patterns. Glancing over the collection, one is struck at once with the fact that most of the cutting-tools are made of old files, in contrast to those bought of Chief Joe, which were mainly made of old knife-blades. The only gravers are files sharpened down at one end to a narrow chisel-like blade. Awls are represented by one specimen only. Still the general character of both collections is very similar. The die-plates are of lead, with holes for both round and pear-shaped stamps,

[1] Since writing the above, I collected a similar outfit from the Oneidas, which is now in the E. T. Tefft Collection in New York.

of different sizes (Plate XXVII, Fig. 11). It will be remembered that Chief Joe's plate to fit the pear-shaped stamp was missing. These stamps differ from those of Chief Joe in having provision for stamping out the halves of the pendants and the loops, for attaching them in the same operation, instead of making the loop of wire and soldering it on afterward as he would have done. All the die-plate holes have been made by hammering the stamps into the soft lead. Two pairs of pincers are of the ordinary commercial variety, although the jaws of one (Plate XXVII, Fig. 12) have been filed small and round for convenience in bending. But the third (Plate XXVII, Fig. 7) has been very ingeniously made of heavy wire, the natural spring of which holds the jaws firmly together. There are also two stamps for making tiny decorative circles on the faces of silver ornaments (Plate XXVII, Fig. 2), an implement also missing at first from Chief Joe's outfit, although obtained on a second visit. To make these, file-fragments have been worked down to a round point, which is truncated, and drilled out so as to produce the required circle when struck against the face of the silver. Another similar implement has simply a small rounded point for making the dots so often seen in the decorations on Iroquois silverwork.

Another unusual article is part of an old file with the end cut into a symmetrical crown-shaped stamp, the imprints of which could be combined in attractive patterns on the larger silver ornaments (Plate XXVII, Fig. 1). Still another implement (Plate XXVII, Fig. 4), resembling a curved chisel with purposely blunted and rounded edges, seems to have been used for rendering convex the narrow band of the single-disk brooch and for similar purposes. One of this kind was later obtained from Chief Joe (Plate XXV, Fig. 2), together with its die. The blowpipe belonging to this set is the regulation form, of iron, and is evidently of white man's make. There are quite a number of broken implements which may be accounted for by the hard and brittle quality of the steel in the files which furnished the material of which so many of the tools were made.

Several implements occur in the Historical Society's collection whose use is a puzzle to me. One is a very old piece of wood in the form of a thick paddle. There are also two stamps made of old files, with triangular stamping-faces which resemble in a certain way the rounded one used for embossing and making hollow ear-pendants (Plate XXVII, Fig. 3); but I have never seen an ornament made with this form of stamp, nor is there a die-plate to fit them in the collection.

There are five patterns, — three of the ornate-disk type, one of the masonic, and one of the typical double-heart form. (Plate XXVII, Figs. 13–17). The last is apparently a silver brooch used as a pattern on account of a crack, which put an end to its value as an ornament. The others are made of zinc, especially for patterns, and show careful workmanship. In appearance they differ from a brooch in having no tongue and in the comparative roughness of some of them. Both curved (Plate XXVII, Figs. 5, 6) and straight chisels are especially well represented in the Society's collection. Besides larger tools already mentioned, there are many odds and ends which the Museum's outfit lacks, such as specimens showing the making of hollow beads, etc., with the die-plate and stamp (Plate XXVII, Fig. 9), a bit of colored glass for setting in an ear-ornament (Plate XXVII, Fig. 8), some rosin for soldering, etc.

The description of the manufacture of silver ornaments presented here was derived from actual observation of some processes, and from descriptions of others furnished by the chief himself. It is not claimed that these are the only methods used by Iroquois silversmiths; but Chief Joe assures me that they were commonly employed by him and by his grandfather before him.

Brooches were usually made out of coins. A coin of proper size having been secured (in this case a Canadian dime), the chief laid it upon the anvil and carefully beat it with a heavy hammer (in this instance a common claw-hammer, because the original was mislaid) until its diameter was increased nearly an inch and its thickness reduced to little more than that desired for the finished brooch. During the process, he took care to keep the pounding evenly distributed and the blank of uniform thickness. The metal was pounded cold, without even annealing. To illustrate this process, I secured a coin pounded out to the proper thickness (Plate XXIII, Fig. 6) for a brooch, and two pieces of a silver spoon thinned out by hammering, to be cut into wires for brooch-tongues and ear-ring loops. The pounding finished, the next task was to smooth the face of the blank with a file, and lay it off along the lines of the future brooch. Chief Joe had planned for a star brooch in this instance, and to this end had made a tin pattern (Plate XXIII, Fig. 27) of approximately the shape and size that he wished for the completed ornament. "We always cut patterns of tin or something cheap," he said, "for all the different kinds of brooches and crosses we want to make." Laying this pattern where he could see it, he perforated the centre of the blank with one of the awls. Then using the pincers as dividers, holding their jaws apart with one of the chisels, he laid off a circle to mark out the central opening of the brooch, the tip of the pincers making distinct scratches. The coin before mentioned, in the Museum collection, has a circle laid off by this means. The points about the periphery, where the rays of the star were to terminate in bosses, were then marked out and the arms themselves indicated. When a good pattern was available, the procedure was somewhat different. Instead of laboriously drawing circles with pincers, and outlining other features freehand, the pattern was laid directly upon the blank, and its outline followed and marked into the silver with an awl or other pointed instrument. The next process was to make the bosses. This was done by laying the edge of the blank over the smallest hole on the die-plate, and forcing the metal into it with the appropriate stamp driven home by a sharp blow of the hammer. (Plates XXVIII and XXIX). This made neat and uniform bosses. The lines made in laying out the brooch were then followed with curved and straight chisels, and the surplus metal cut away, leaving the star brooch nearly completed. During the whole cutting-process, the blank lay upon the anvil. The next step was to smooth and trim the edges with a file, then to decorate the surface of the brooch. The second unfinished brooch in the collection illustrates this stage (Plate XXIII, Fig. 12). The so-called engraving was done more by stamping than by cutting, although no regular form of stamp was used. The straight chisel, lightly tapped, made a fairly long straight line. Round and triangular dots were formed by implements whose points had been filed into shape for the purpose. Curved lines and ovals were made by combining the imprints of curved-edge chisels; while short straight lines were the imprints of the chisel-like gravers. Two or more such graver-strokes made crosses. The most important use of the gravers, however, lay in making the zigzag lines, frequently of extreme delicacy and fineness, which form some of the most striking and artistic patterns found on the Iroquois ornaments. In this case the graver is not struck with the hammer, but is pressed firmly against the silver, and pushed forward with a strutting motion; the hand holding the graver moving from side to side the while. It is remarkable to note the skill with which this instrument is guided. As might be expected, the small zigzags are produced with a fine graver, the larger with a graver of broader edge.

When the brooch had been engraved, the next step was to perforate (with an awl) a small hole near the edge of the central opening to receive the hinge-end of the tongue. To make the tongue, a slender strip or wire was cut with the straight chisel from a larger piece of silver, as is shown by the hammered spoon-handle mentioned before, and this was filed and bent into proper shape, and put into place. The brooch was then completed.

As before intimated, the convex hollow circlet of the simple-disk brooch was made by driving the edge of a flat disk of silver into the circular groove of the specially made die-plate by repeated strokes of a suitable punch (Plate XXV, Figs. 1, 2), thus forming an embossed circle. The metal within the circle was then cut out and the edges trimmed, when the ornament needed only polishing and a tongue to be complete. An unfinished brooch of this kind is shown in Plate XXIII, Fig. 17.

Making ear-ornaments was more difficult, because these often required hollow drops and pendants, and sometimes settings of colored glass, as well as a hinged wire loop to go through the ear. Of course, in the plain hoop ear-rings these difficulties did not appear. The silver was hammered out, marked off, and cut in approximately the same way as for brooches. For the hemispherical or chestnut ear-drops (the most common shape), two circular pieces of silver were cut out, one larger than the other. The latter was laid over the largest hole in the die-plate, and driven in with the proper punch and a hammer until it formed a hollow hemisphere. When the edge had been filed, the opening was closed with the flat circular disk, and the two soldered together. This was effected by placing between them a few bits of lead, and holding them over the flame of the lamp by means of the pincers, turning them as the lead melted. The pear-shaped pendants were also hollow, and prepared in two parts (equal this time), and pressed into form in a pear-shaped die (missing from our set) with the pear-shaped stamp. Most of the hollow ear-drops exhibit decorative engraved patterns, while the pendants show designs formed by grooves in the metal. When I asked Chief Joe how these were made, his answer, as nearly as I could understand it, was to the effect that the decoration on the drops was made with a file and small punch after the pressing was done, but that, with regard to the pendants, the dies and stamps were themselves engraved with the patterns beforehand, which were thus consequently communicated to the silver. The part concerning the ear-drops is evidently true; but, on thinking it over, I have come to the conclusion, that as all the dies and stamps I have seen have been plain, and all the hollow ear-pendants decorated, he must have meant that the patterns were stamped into the silver before the metal was pressed into form. The setting of ear-drops and pendants with pieces of colored glass was effected by first cutting a long flat strip of silver with a series of equal projecting points along one side; then this was bent into the form of the setting, and soldered fast, on edge, upon the face of the ear-drop; the points, of course, being upward. When the glass had been inserted, the points were bent down, holding it firmly. Sometimes an embossed sheet of silver, cut to proper form, was placed beneath the glass, so that the patterns would show through. The glass was shaped with a file. The wires intended to pass through the ear-lobes were, like the tongues of the brooches, first cut with a straight chisel from a large piece of hammered silver; and there were four pieces in all, two for each ear. The ends of two of these short wires were split with the straight chisel, and spread with the spreader before mentioned. The ends of the other two were then filed into tongues, fitted into the splits, and riveted fast, forming hinges. There were now two wires, which were filed round and smooth, then bent carefully and slowly with the aid of the pincers into a C-shape, one end of which was soldered upon the lower edge of the back of the ear-drop, the other fitted into a little hole or socket near the upper edge, as shown in Fig. 2. This held the ornament secure when in use.

Head-bands and armlets required another process, casting, which was accomplished in a simple and, to my mind, ingenious way by means of the hardwood moulds previously described. When in use, the trough of the mould was filled with glowing hardwood coals upon which were distributed bits of silver in sufficient quantity to fill the mould when melted. Then the wooden blowpipe came into play; and the coals, by steady blowing, glowed with so much heat that the silver melted, and ran down into the mould below. Sometimes, in order to get the metal into such shape that it would be evenly distributed, it was necessary to cast a number of small bars in the small mould, and then cut them up to be laid upon the coals of one of the large ones. The bar, once cast, was carefully hammered thin, growing larger and broader with every stroke until the proper dimensions were reached. It was then filed smooth, laid off, fluted, cut, and engraved in much the same manner as a brooch. Frequently the head-bands show the art of the Iroquois silversmith at its best. Everything is dainty, symmetrical, artistically planned, practically perfect. The fluting was done with a wide chisel whose edge had been purposely blunted and rounded.

Chief Joe did not mention finger-rings; but these were apparently often made in two pieces, which we may call the band and the seal. These were soldered together after being cut out, decorated, and bent by processes before described. As before mentioned, some rings were plain bands. Others had no seals attached separately; but the band was broadened and decorated at some one point, producing the same effect.

Before concluding, a few words concerning the origin of the art of silversmithing among the Iroquois may not be out of place. Of course, such a discussion must necessarily be almost entirely theoretical. Taking the brooches first, it seems possible that we may look for their ultimate origin in the ornaments of copper, mica, and other materials thought to have been sewed or tied upon garments as ornaments by many tribes of the preçolonial period. As Beauchamp says, "Apparently the brooch was an evolution from the gorget, for some (early) ornaments of this kind were tied on, not buckled." He mentions and figures such a crude brooch-like ornament of copper found on an Onondaga site of 1677.[1] It is difficult to surmise how the buckle-tongue fastening originated, or, if borrowed, whence it came.

[1] Beauchamp, Metallic Ornaments of the New York Indians, p. 77. Moore found brooch-like gorgets of copper in prehistoric Alabama mounds (Moore, Certain Aboriginal Remains of the Black Warrior River, pp. 198, 219).

Perhaps the idea was in some way derived from the old-fashioned shoe or belt buckles of the colonists. Examining the patterns, the Masonic type speaks for itself, as being clearly of European origin; but the other forms are not so easily traced. The heart-type, surmounted by an apparent crown, looks suspiciously European also; but we cannot prove that the heart, which occurs so often in all kinds of Iroquois carving and beadwork, is not a pattern native to the people. The crown-shaped ornament above possibly represents a feathered head-dress, or sometimes an owl's head.

As for the star-form, we can find similar many-rayed designs on the painted robes of the Plains Indians. Squier [1] reports an ornament in the shape of a four-pointed star, made of copper and shell wrapped in thin beaten silver, found in a prehistoric mound at Mound City, O. It is not even necessary to suppose that the silver head-bands of the Iroquois were copies of the royal crowns of England or France. Granted that the Indians could invent a star-shaped brooch whose rays terminate in bosses, they would very naturally cut the top of the silver head-band into similar ornamental rays. Still the resemblance to a crown is at least a remarkable coincidence.

In form and especially detail, the ear-ornaments show considerable originality; but in the hinged wire loops for attachment to the ear we see a European invention. Italian women on the streets of New York to-day wear ear-rings fastened in the same identical fashion. The custom of wearing metallic ear-ornaments is, however, of by no means recent origin in North America. The so-called "mound-builders" wore spool-shaped ear-plugs of copper, often coated with thin hammered silver. Squier quotes an account of the Virginia Indians of the sixteenth century,[2] in which an explorer reports that he saw "two small pieces of silver grossly beaten, hanging from the ears of a Wiroance." Turning to the decoration, we see that one ear-ring pattern, the spread eagle with scroll and shield, is plainly derived from that stamped on United States coins; yet I have seen hawk and other bird patterns that were not necessarily borrowed. The finger-ring is probably a relic of Jesuit influence, as are the silver crosses occasionally seen. Arm-bands are probably of ancient origin, at least in idea.

As for the art as a whole, its origin is not made clearer by what can be learned from observations on different ornaments themselves and their possible beginnings. We know that several prehistoric Indian peoples in the eastern part of North America were experts at hammering copper, embossing, engraving, and excising the metal much as the Iroquois do silver; and it is reported that they sometimes used silver also. Some of their products will bear favorable comparison with the best works of Iroquois silver-

[1] Squier, Antiquities of the State of New York, p. 291.
[2] Heriots Voyages, 1586, in Pinkerton, Vol. XII, p. 574.

smiths, with all the latter's modern tools. There are even spread-eagle and brooch-like patterns found on copper plates in the mounds [1] in such widely separated localities as Georgia and Illinois. Thomas, however, thinks these copper ornaments were probably made with European tools or by Europeans, simply on the ground that they are too good to be the work of a stone-age people. But other authorities, such as Putnam and Saville, disagree with him; and the inimitable Cushing [2] clinched the matter by reproducing the ornaments, with all their embossing and openwork, from a nugget of copper with stone and bone implements only. The simple and ingenious methods by which these results were obtained he learned from the Zuñi Indians.

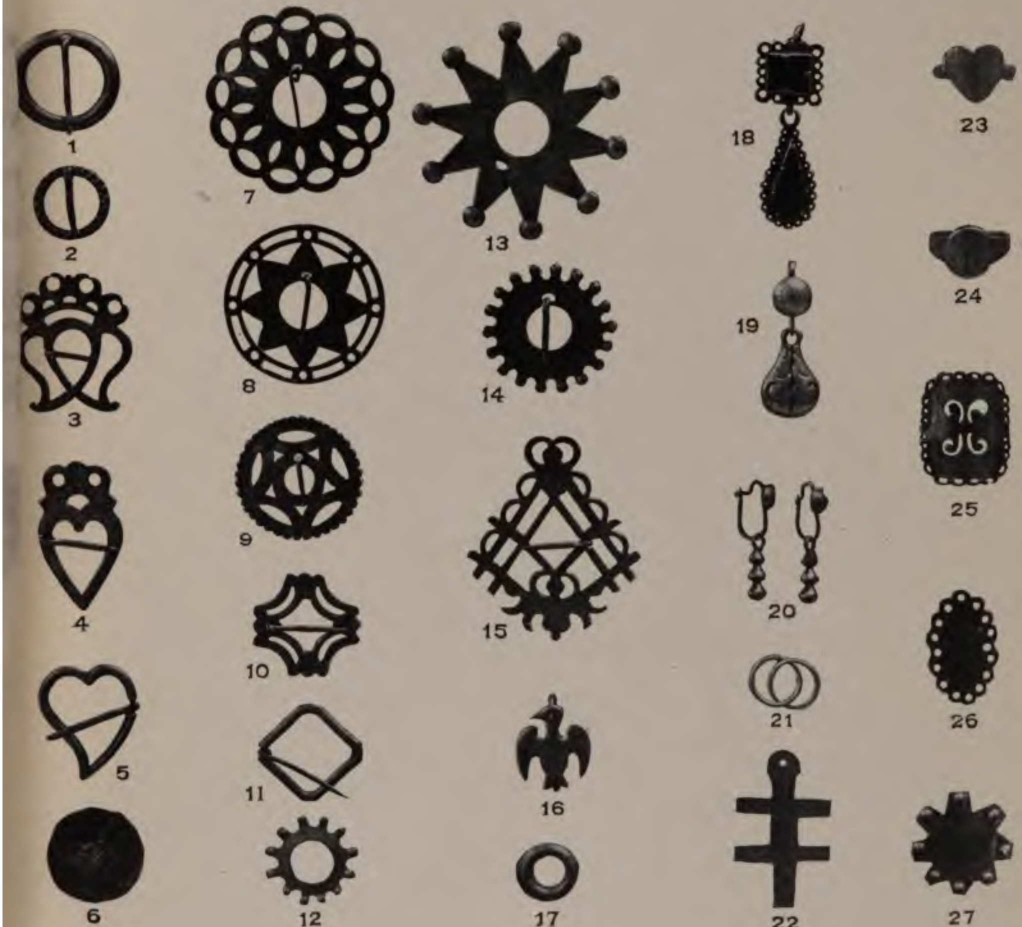
I think I have made it clear that it is, then, not necessary to look outside of America for the mother of the Iroquois art of silversmithing. It is also plain that European influence was very powerful both at its birth and during its development. In fact, if we call the ancient American hammering of metal the mother of this art, we can say that its father came from across the ocean. Nevertheless, it has acquired a character all its own, and bears the impress, not only of the adaptability of the Iroquois, but of his originality. In this light we may consider it worthy of study.

In conclusion, a partial list suggesting the wide distribution of silver ornaments among the Indians may prove of interest. No attempt has been made at completeness, the data being only such as have come to my notice. To my personal knowledge, silver ornaments have been made by the following tribes: Oneida, Onondaga, Cayuga, Seneca, Delaware, eastern Ojibwa, Seminole of Florida, Chotaw of Mississippi, and Koasati of Louisiana. The silversmith's art of the Navajo and some tribes of the northwest coast is, of course, well known. Among the other tribes from whom silver ornaments have been reported are the Tuscarora, Mohawk, Cherokee, Mohegan, Penobscot, Micmac, Sac and Fox, Dakota, Pawnee, Osage, Acoma, Apache, Yuchi, Creek (other than Koasati), and Chitimacha.[3] It is not certain whether all of these tribes manufacture such articles, but the probabilities are that many of them do so. Most tribes addicted to silver ornaments use some of white man's make, and some obtained from other tribes in addition to those of home manufacture.

Further investigation of the distribution and character of Indian silversmithing might lead to interesting results regarding the origin and dissemination of that art. I suspect that the southeast might furnish the connecting

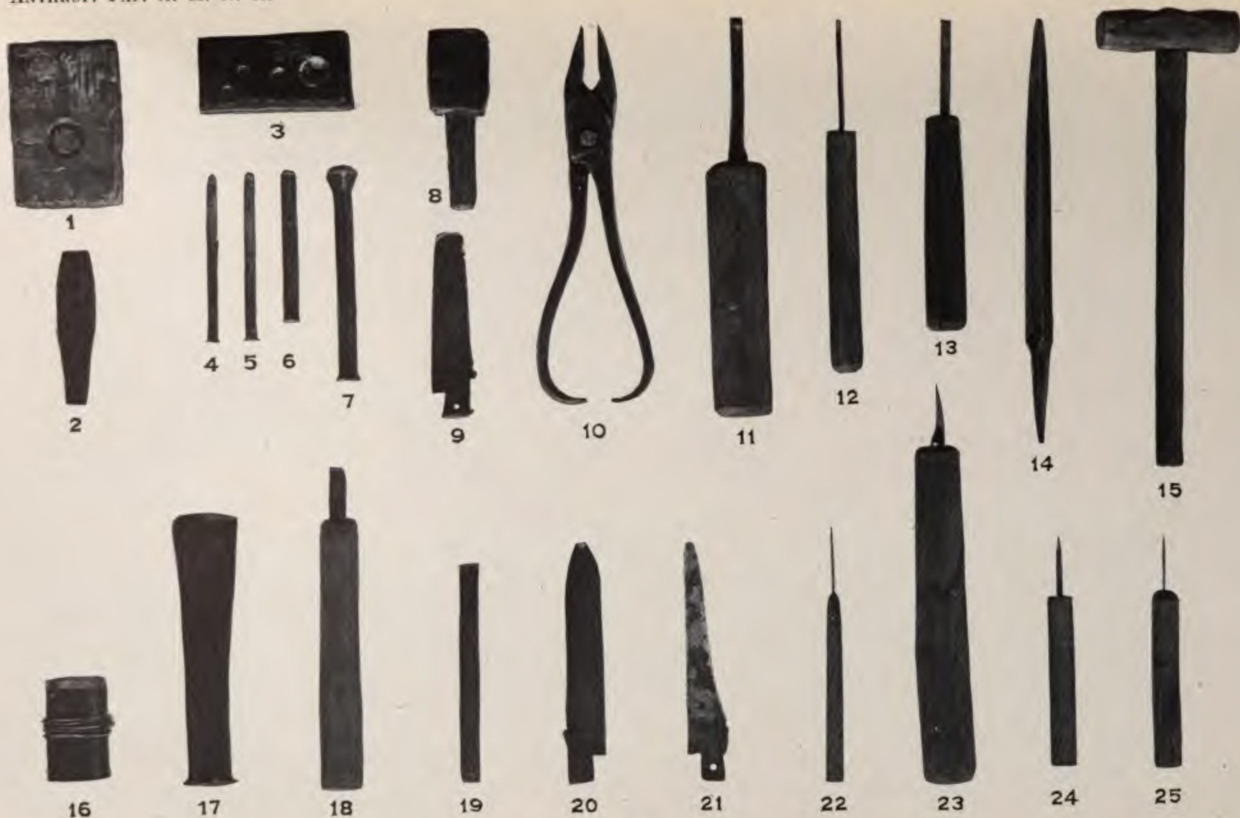
[1] Thomas, Mound Explorations (12th Annual Report of the Bureau of Ethnology), Plate XVII, and Fig. 192.
[2] Cushing, Primitive Copper Working (American Anthropologist, January, 1894).
[3] The Museum collections contain silver ornaments from the Dakota Pawnee, Fox, Ojibwa, and Delaware Indians in addition to those of Iroquois origin. For Dakota designs on silver, see this publication, Vol. I, Part II, pp. 44, 52.

link between the metal-working of historic and prehistoric times; for many of the silver brooches and pendants of the Seminole and other Muskhogean peoples present a strong similarity to the prehistoric ornaments of copper found by Moore in the mounds of the region formerly their home.



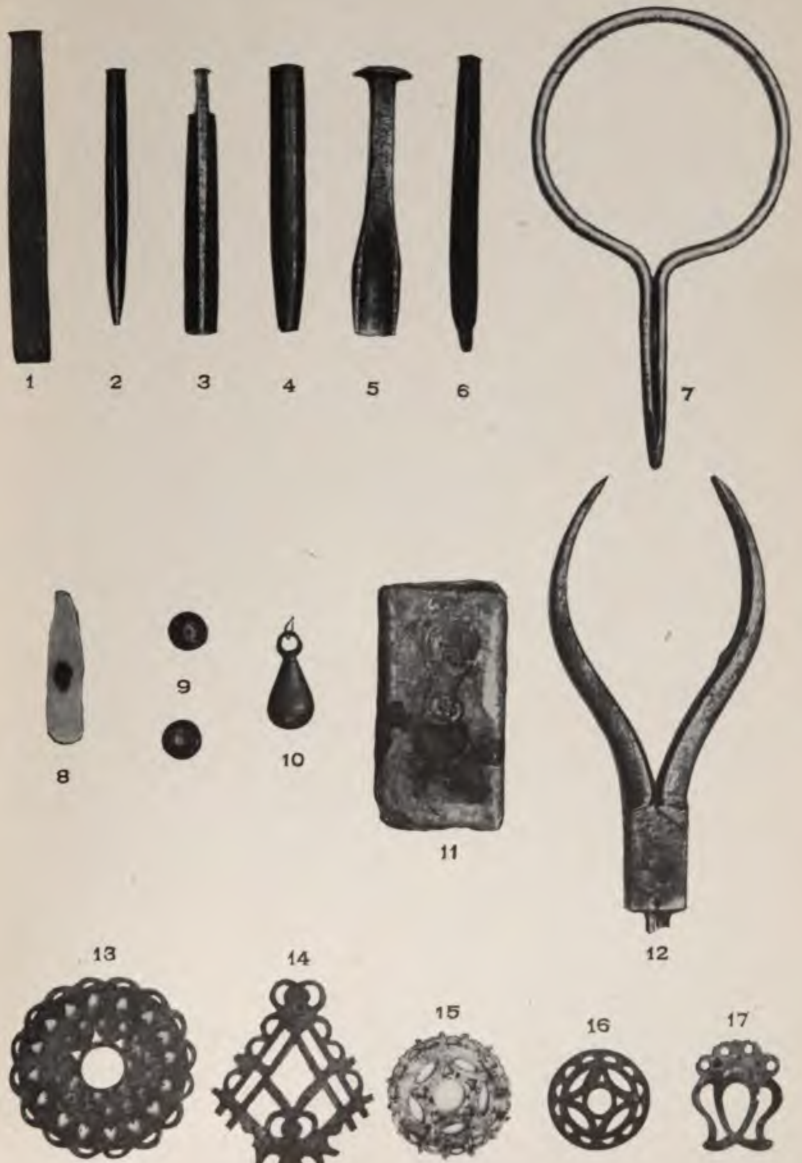
Brooches, Rings and Ear-Rings.

HEAD–DRESS AND BRACELETS



SILVERSMITH'S TOOLS.

SILVERSMITH'S TOOLS.



ADDITIONAL FORMS FROM THE MONTGOMERY COUNTY HISTORICAL SOCIETY COLLECTION.

HAMMERING OUT A COIN.

EMBOSSING.

ANTHROPOLOGICAL PAPERS

OF THE

American Museum of Natural History.

Vol. I, Part V.

THE HARD PALATE IN NORMAL AND FEEBLE-MINDED INDIVIDUALS.

BY

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CONTENTS.

ILLUSTRATIONS.

PLATES.

Text Figures.

TABLES.

INTRODUCTION.

This paper discusses some measurements made upon casts of the hard palate in living subjects. These casts are from both normal and feeble-minded individuals, representing by far the largest and most unique accumulation of such material so far brought to our attention. They were systematically collected by Dr. Walter Channing in response to his interest in the much discussed question of correlations between certain variations of the hard palate and states of feeble-mindedness. For this reason, the junior author made a rather detailed comparative study of the two series, his chief interest being in the application of anthropometric methods to this type of anthropological data.

In 1897 Dr. Channing published a paper in "The Journal of Mental Science," entitled "The Significance of Palatal Deformities in Idiots." His attention had been directed to certain theories concerning idiots' palates, which had been advanced upwards of thirty years ago by Dr. J. Langdon Down, who was at the head of the Earlswood Asylum for the Feeble-minded in England.

Dr. Down had said, "I have made a very large number of careful measurements of the mouths of the congenitally feeble-minded and of intelligent persons of the same age, with the result of indicating, with some few exceptions, a markedly diminished width between the posterior bicuspids of the two sides. . . . One result, or rather one accompaniment, of this narrowing, is the inordinate vaulting of the palate, which assumes a roof-like form. The vaulting is not simply apparent from the approximation of the two sides, it is absolute; the line of junction between occupying a higher plane." [1]

Dr. Down further stated that the "V-shaped" palate was characteristic of a very large class of idiots, and that a certain peculiar shaped palate was pathognomonic of congenital idiocy.

Dr. Norman W. Kingsley, an able and reliable American dentist who did not agree with the conclusions of Dr. Down, visited the Earlswood

[1] Mental Affections of Childhood and Youth, p. 281, 1887.

Asylum, and in company with Dr. Down examined the palates of the inmates. "Together," Dr. Kingsley says, "we made a careful examination of every inmate of the institution, with a result not so widely different as I supposed must exist. There were, to be sure, a larger percentage of irregularities of the teeth than I had before observed. About two per cent might be said to be pronounced cases of narrowed or V-shaped arches, and another five to ten per cent might be said to have more or less tendency in that direction; but of the more positive cases I did not see one so marked as I have seen and treated in private practice, and associated with full intellectual development." [1]

This refutation by Dr. Kingsley, which was certainly authoritative enough to leave the question still open for discussion, appears to have received little attention.

The conclusions of Dr. Down thus assumed an importance to which at this time they do not seem entitled, because they were the first formulation of the relation and significance of certain palatal shapes to feeble-mindedness, and because they were accepted by many writers as essentially correct. At a later date, when stigmata of degeneracy began to be exploited until there was almost a stigma cult, Dr. Down's theories concerning the palate aroused renewed interest, indicating as they did that the palate was the seat of the most pronounced stigmata.

To test the correctness of Dr. Down's conclusions by a more thorough study than had yet been made, and incidentally to determine, if possible, how much weight should be attached to palatal shapes as stigmata of degeneracy, Dr. Channing had casts made of the palates of a thousand feeble-minded individuals and five hundred school-children.

The conclusions which he arrived at as a result of his studies were as follows: —

"1. Two-fifths of the palates of idiots are of fairly good shape.

"2. Palates of normal individuals may be deformed.

"3. In the idiot it is a difference in degree, and not in kind.

"4. In either case it shows irregular development anatomically.

"5. Palates of average children and idiots, under eight years of age, probably do not in the majority of cases markedly differ.

"6. There is no form of palate peculiar to idiocy.

"7. The statement that a V-shaped or other variety of palate is a 'stigma of degeneracy' remains to be proved." [2]

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[1] An Inquiry into the Causes of Irregularities in the Development of the Teeth, New York, 1875.

[2] The Significance of Palatal Deformities in Idiots (The Journal of Mental Science, January, 1897).

Dr. Channing, in his published paper, made the further statement that, "as far as the idiotic or feeble-minded are concerned, I believe the deformed palate to be only one of an indefinite number of indications of imperfect anatomical development, occurring, to a marked or very slight degree, as hereditary and environmental causes may determine."

This statement, and the conclusions summarized in the paper referred to, met in the beginning with some opposition, which has grown less as time has gone on. At the present time we hear much less of the *stigmata of degeneracy;* the whole subject of these stigmata having been brought into disrepute by the exaggeration of past years, and its value and significance placed under suspicion. We may say now, that apparent defects or deviations from the normal are not dignified as *stigmata,* unless the claims that they are such are based on satisfactory scientific data. There still are writers, however, who continue to reason along the old lines; the recent data available not being of a sufficiently convincing nature to impress them, or extreme conservatism or preconceived opinion rendering them unwilling to accept new views.

During the ten years since Dr. Channing published his paper, nothing new has been brought forward to lead him to modify the views he then expressed. In the interest of research, however, we have thought it desirable to make a new study of the casts collected by Dr. Channing, recently augmented by the addition of a large number of those of normal individuals, for the purpose of retraversing former conclusions, and proving or disproving them.

In the paper of Dr. Channing already referred to, the claim was made that the most satisfactory results in the study of palates could be got from casts, and a classification was made based on shapes. We are still of the opinion that casts must be used, if a convincing and conclusive inquiry into the subject of palatal deformities is to be made.

COMPARISONS BY MEASUREMENT.

Recent developments in statistical methods have made anthropometric research fruitful. Unfortunately, these methods are not sufficiently well known for us to proceed without, at least, a few general statements.

All problems involving comparisons of morphological types must concern themselves with variation. Certain general assumptions underlie all procedure in such problems. A morphological type is a complex result of causes imperfectly known and little understood. It is assumed, that, whatever may be the number and nature of the causes tending to project an organ into space, the objective is definite, constant, and fixed. For the hand, we assume a definite form of fixed dimensions to the realization of which biological forces tend. This assumption is based upon observed facts. Experience has made it apparent that the space-values for the several organs of a group bear a fixed relation to each other; that is to say, as measured, the space-values of individual organs cluster around a median value in a constant relation. The additional observation has been made, that this relation is the same as that found in a combined result due to a large number of independent causes. The phenomena of chance as considered in mathematics present the same relations. If we take a bag of coins and throw them upon a table, we get a number of heads; if we make a thousand or more successive throws and record the number of heads for each, we obtain an array of values or frequencies that cluster around a median frequency. Mathematics is able to analyze this case, and determine the principle involved from which the result of this tossing of coins can be foretold.

Let n = the number of coins thrown at a time
p = probability that a coin will fall head
q = probability that a coin will fall tail
$p + q$ = probability that a coin will fall

Then

$$p + q = (\tfrac{1}{2} + \tfrac{1}{2}) = 1$$

$(p + q)$ = number and kind of possible combinations.

The coefficients of the expansion of this binomial will give us the expected frequencies for each possible combination of heads and tails. The average of these coefficients will be np, the maximum coefficient.

If we consider the coefficients as ordinates of a curve, np will be the maximum ordinate, and equal distances right and left upon the abscissa will locate equal ordinates. Thus a binomial expression of the above form may be defined by the value of the maximum ordinate and the units of the abscissa taken.

In morphological measurements it is observed, that if units of size be represented on the abscissa, and the frequencies of occurrence upon the ordinates, the relations between them are similar to those in the binomial expression. Yet we do not know the value of n or the number of causes that are involved in the production of the organ measured. Also size is continuous, and is represented by each point in the abscissa. Thus the recorded measurements of size are arbitrary units of the abscissa, and the frequencies for these units express the number of cases falling within their respective limits. To express such a relation, a different formula is needed, which will be found in the literature of statistical measurements. For our purpose it is sufficient to state, that, whenever frequencies are found to agree with this formula, there is a constant relation between the frequencies and distances upon the abscissa, measured from the maximum ordinate. This constant is known as the standard variation, expressed in the following pages by σ. In the binomial formula,

$$\sigma = \sqrt{npq}$$

σ is also the square root of the average of the squares of all the individual differences from the average. Thus it represents the variation of the organs measured from their average. We can now define the type of an organ by stating its average and its standard variation, or its A and its σ. Since σ is measured from the average, it is written as $\pm \sigma$: hence our expression becomes

$$A \pm \sigma$$

It is obvious that, since σ represents a constant in the abscissa of a fixed curve, all its calculated values will be relatively equal. Thus, by use of the same unit of measure for two groups of organs, we may compare the objective magnitudes of their variations.

In this work we have made use of certain principles of procedure well known in statistical methods.

(*a*) The range of variation is regarded as infinite, but practically restricted to $A \pm 4.5\,\sigma$. Upon the same basis, the frequency for any multiple of σ can be determined by calculation.

(*b*) When groups of measurements are combined into one group, the σ for the whole will be the square root of the sum of the squares of the σ's for the constituents; as

$$\sigma_s = \sqrt{\sigma_1^2 + \sigma_2^2 \ldots + \sigma_n^2}$$

(*c*) When the number of observations is small, the average obtained will vary from the true average, or the type. This variation will be accidental, and conform to the laws of chance or the exponential formula. Thus the average will have a standard variation of its own, which we have expressed by ε. It can be shown that

$$\epsilon = \sigma \frac{\sigma}{\sqrt{n}}$$

in which n represents the number of observations. This value is necessary to the comparison of averages, for, unless the difference between two averages is such that one falls with certainty outside the normal accidental range of the other, they must be regarded as belonging to the same type.

(*d*) Correlation. This is a method by which it is assumed that we can measure relation, or the dependence of one complex variable upon another. In physical measurements it is assumed that causes tending to produce size operate upon the several morphological organs, and that the causes that tend to make a man tall may be said to tend to make him heavy also. Yet other causes tend to vary his stature, and still others his weight. The consequence is, that his stature-weight dimension, or the proportion between the two, is a resultant of all the various forces involved. The method of correlation assumes to measure the degree to which the causes tending to realize a size-type function in a given case. The method is a geometric one, and expresses its results in like terms. It attempts to analyze a resultant of forces, and is in so far analogous to problems in physics. The justification of the method and the application must be sought in the literature of statistical methods.

The measurements upon which the following discussion is based were made with an apparatus devised by Professor Franz Boas for the anthropological laboratory of the American Museum of Natural History, New York City. The mechanical principles of the apparatus are simple. Movable points are so related as to be adjustable in three planes intersecting at right angles. When an object has been placed upon the table of the apparatus, and adjusted to one of its planes, readings may be taken for points in all three planes. Thus the cast of a palate may be placed upon a support of sculptor's clay, and adjusted by trial until the plane of the teeth coincides with the horizontal plane of the apparatus. Then, if we choose the two first molars as a base, the adjustment is easily made so that the line joining them will pass through the points of intersection for the three planes, and, with the molars as the point of departure, we may then define the location of other points on the cast. It was by virtue of this apparatus that we were able to make satisfactory measurements, and any comparison of our results with other measurements must take into account this fact; i.e., that the measurements here given were made in geometrical planes carefully determined, and not subject to the error resulting from measurements taken freehand with calipers.

In all measurements the question of accuracy is important. It is not so necessary that measurements should be absolutely accurate, for that is a relative term at best, as that the degree of accuracy should be known. In one case, errors will occur in the determination of the plane of the teeth, the reading of the dimensions upon the scales of the apparatus, and the location of the points from which the measurements are projected. The degree of such error can be estimated by repeating the whole measurement. To this end we made two independent measurements of the width at the molars in case of adult males. Taking the first measurement as fixed, and taking the difference between it and the second measurement as positive or negative, as the case may be, we find an average difference of -0.7 mm. Theoretically this should be 0. The standard deviation for the differences is ± 0.9 mm. Since this is the combined variability for the two measurements, neither of which is correct, the variability due to error should be apportioned between them. Let

σ_1, σ_2 = the respective variabilities of the error of measurement.

Then

$$0.9 = \sqrt{\sigma_1^2 + \sigma_2^2}$$

Assuming that

$$\sigma_1^2 = \sigma_2^2$$

$$\sigma = 0.6 \text{ mm.}$$

Hence the variability of the error becomes ± 0.6 mm. Then the chances that an error will exceed one millimetre are very small. As all of the measurements were made in the same way and by the same person, this error can be taken as constant, and ignored in the comparative results.

Since no extended studies by measurement have come to our notice, we have omitted a review of the general literature of the subject, on the ground that such a discussion would take us too far afield. As previously stated, our present purpose is to approach the problem from the anthropometric point of view. About three years ago we published a brief report on the work in "The American Journal of Insanity," Vol. LXI, No. 4, April, 1905.

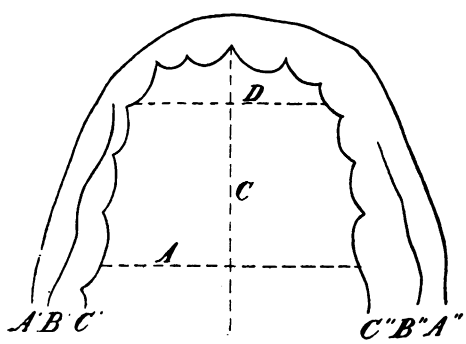

Fig. 1. Diagram of Palate.

Type of Palate for the Normal-minded.[1] — The preliminary problem is the determination of the points from which measurements are to be made. If we look down upon the upturned cast of the hard palate and the teeth, several lines stand out clearly (Fig. 1). For one, we have the curve of the teeth $A'A''$. This curve follows the edge of the

[1] The junior author is responsible for the choice of this term. It seems best in this case, because the subjects were selected according to general mental condition; and while it is reasonable to assume that those not considered feeble-minded were physically normal, the use of the general term may imply that all palates among the normal-minded were normal. Thus a confusion of terms may lead to an entirely different interpretation of the results obtained.

incisors and the outer ridge of the bicuspids and molars. If we are concerned with the teeth alone, this is the most important point of regard. Disregarding the teeth and giving our attention to the form of the cavity, we find the curve $C'C''$. While in the diagram this curve seems more irregular than $A'A''$, it should be remembered that the outer curve is also broken in that it is defined by the points upon the successive teeth; whereas the inner curve is defined by the corresponding inner surfaces of the teeth. An examination of the skull will show that this curve is closely correlated with the curve of the maxillary process, or the contour of the hard palate. The surfaces of the molars and bicuspids have well-defined median lines that may prove more reliable points of regard than their outer edges. Should this line be taken, the curve will then turn from the apex of the outer incisor, across the canine, to the median line of the bicuspid, $B'B''$.

Now, any attempt to determine correlations between the form of the palate and other variations from the morphological type must find a means of stating the type of one of these curves, and, as these three curves are closely related geometrically, the choice must be determined by economy of methods of measurement and the end in view. These curves can be treated according to their length and their form. If the form is strictly symmetrical, the distance between corresponding points upon the teeth, as upon the first molars for example, will give twice the ordinate for a point upon the abscissa, or the median line of the palate. In the diagram, A represents the distance between the molars; and C, the distance from the alveolar point. The abscissa, or the median line of the palate, is not clearly defined in the casts, and, even in the case of the skeleton, variability makes the true determination of the median line difficult: hence the only practical thing to do is to measure the distances corresponding to A and the line C, as determined by A and the alveolar point. As we shall see later, the values of these lines will enable us to approximate the form and size of the curves.

In the first place we investigated the variability as measured from different points in the transverse plane of the first molars. The following values were obtained: —

	n	A	σ	V
		mm.	mm.	mm.
From outer edges	96	54.7	3.75	0.27
From median line	101	47.4	3.37	0.24
From inside	126	34.7	3.35	0.21

Since v represents the accidental range of σ, it is clear that the degree of variability in the three measurements does not differ by an amount greater than the range of accident. It is also apparent that the variability in the width of the teeth is relatively small. If we assume the above variabilities as fixed and absolute, the estimated combined variability for the inner halves of the molars is expressed by x in the following equation: —

$$3.37 = \sqrt{(3.35) + x^2}$$
$$x = \pm 0.36$$

By the same formula, the variability of one molar from its median plane would be about ± 0.25 mm.

From the above it seems that the standard deviation for the width of the entire molar will be about ± 0.4 mm.

These results make it probable that it is immaterial whether measurements are taken from the inside of the teeth, from the median line of the teeth, or from their outside edges. The small degree of absolute variability in the size of the teeth enables us to regard them as constants. Hence, in considering the size of the palate, the measurements may be taken without regard to the size of the teeth.

There are, however, other considerations in making a choice as to measurements. We have data for all ages, from six years to adult life; and this span includes two dentition periods, — the so-called second dentition and the eruption of the wisdom-teeth. Thus the loss of teeth and the maturity of the incoming teeth will modify the measurements in various ways. For these reasons it was decided to measure the palates according to the inner curve of the teeth at the gum-line. The justification of this choice will appear later.

Our preliminary problem is clear. We must first determine the type of the normal adult palate. For this purpose we took the casts of 126 adult males (chosen at random), and subjected them to a number of measurements. The inner widths for all the teeth, except the third molars, were found, as well as the outer widths, and in addition the length, or distance from the alveolar point as measured on the abscissa. The results are given in Table I.

TABLE I. MEASUREMENTS OF WIDTHS AND LENGTHS.

	Inside Width.	Inside Length.	Outside Width.	Outside Length.
	mm.	mm.	mm.	mm.
Outer incisors	17.15±2.10	4.33±1.06	22.17±2.20	4.06±1.36
Canines	22.92±2.51	6.90±1.50	34.19±2.75	9.73±2.00
First bicuspids	26.26±4.01	12.39±1.91	41.79±2.95	16.84±2.36
Second bicuspids	30.82±3.28	19.06±2.22	47.08±3.10	23.23±2.76
First molars	34.75±3.35	28.71±2.58	54.71±3.75	34.26±3.30
Second molars	38.96±3.12	38.04±2.98	58.72±3.18	42.92±3.94

In taking these measurements, the minimum distances between the bicuspids and the molars were taken. The mechanical conditions are such that this can be done with a fair degree of accuracy; yet the normal positions of the canines and the incisors are such that the measurements must be taken from the approximate middle points, or the transverse median planes of the teeth. As these points must be estimated by the eye, the variabilities of the measurements must be greater than in the preceding cases; but inspection of the dimensions involved indicates that, in locating the point, an error of one millimetre is extremely improbable. Furthermore, it will be observed that the calculated standard deviation for the measurements at the canines and the incisors does not differ from the other measurements by an appreciable relative amount.

While we have in this table the averages and their probable ranges for points on each tooth, it will be difficult to plot correctly the type of the palate. Thus if we take three points (the alveolar and the first molars), we have the abscissa and an ordinate for the curve of the palate (Fig. 2). We know the average length of $A'A''$ and $C'C''$ as perpendicular to $A'A''$. The points A', A'', and C', cannot be taken as fixed, unless we assume the morphological development of the organ to proceed from one of these points as an origin. It is obvious that no such assumption is justifiable, for each point is a variable. That the organ does tend to realize a type seems a reasonable assumption; and the biological point of view is, that the development of the body proceeds from its median plane. Thus it may be justifiable to consider the median plane as fixed. However, this does not solve our difficulty, since C becomes a variable point in the median plane of the body, or in a straight line. If all the palates were balanced in a common median and a transverse plane, taking these at right angles to each other, C' would vary according to the size of the palate (let $C'C''$ be the median plane, and $A'A''$ a line in the horizontal plane); yet our measurements give us neither the location of C'' nor the value of the angle a, and our material is such that the median planes of the individual palates cannot be determined with reasonable accuracy. Hence the problem must be approached indirectly.

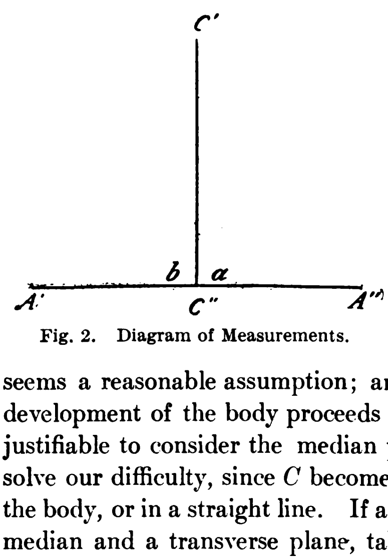

Fig. 2. Diagram of Measurements.

If we can assume that the palate is developed symmetrically around the median plane, the angle a will on the average approximate a right angle, and the line $C'C''$ will bisect $A'A''$. It is also evident that, if the observed values $A'C''$ and $C''A''$ are equal on the average when $C'C''$ is taken perpendicular to $A'A''$, the average measurement of the angle a is 90°. Hence, if we determine empirically the value of $A'C''$ and $C''A''$, we shall have established a point in the typical palate.

For this purpose we measured fifty normal and fifty feeble-minded adult males for the values of $A'C''$ and $C''A''$, the results of which are given in Table II. $A'C''$ represents the half of the palate belonging to the right side of the body, and $C''A''$ that belonging to the left. The entire data are given. The differences between the two halves of the palates of normal and feeble-minded males average approximately one millimetre. While this is almost twice the probable deviation of the difference, it cannot be taken as significant. The fact that the two groups of measurements vary in the same direction (the right side being the larger) may be given some weight.

TABLE II. MEASUREMENTS OF ASYMMETRY.

	Normal-Minded Males.		Feeble-Minded Males.	
mm.	$A'C''$	$C''A''$	$A'C''$	$C''A''$
7	–	–	–	1
8	–	–	–	0
9	–	1	–	0
10	–	–	–	1
11	1	2	1	0
12	0	3	1	3
13	0	2	1	1
14	5	1	2	3
15	4	3	4	6
16	2	4	5	6
17	5	10	6	5
18	11	10	10	10
19	10	6	9	7
20	5	3	5	5
21	4	2	5	2
22	1	1	1	–
23	1	1	–	–
24	1	1	–	–
n	50	50	50	50
Average . . .	17.98	17.02	17.68	16.68
σ	±2.37	±2.82	±2.37	±2.81
ϵ	±0.34	±0.39	±0.34	±0.39
Certainty of difference . .	0.96±0.52		1.00±0.52	

Before going on, it may not be out of place to consider the effect of small error in measurement upon the symmetry as obtained. Referring to Tables IV and V, we find the average widths at the molars to be 34.7 mm. for the normal adult males, and 33.8 mm. for the feeble-minded. By adding the two averages in Table II, we have 35 mm. and 34.4 mm. respectively. The difference between these values contains not only the variation due to a smaller number of cases expressed by ε, but the error introduced by the readings in millimetres. Such error will be made when the line $A'A''$ is expressed in an odd number of millimetres, and $A'C'' = C''A''$; the result being recorded as $A'C'' >$ or $< C''A''$. Though these differences should cancel each other in the long-run, they will, with so small a number of cases as we have at hand, still be a disturbing factor. We can form some estimate of the effect of this factor by referring to the standard variations. For feeble-minded adult males, $\sigma = 3.61$ for $A'A''$. This should equal the square root of the sum of the squares of the σ's for $A'C''$ and $C''A''$. Let d be the amount of the disturbance. Then

$$3.61 = \sqrt{(2.37)^2 + (2.81)^2 + d}$$

$$\because \quad d = -0.06 \text{ mm.}$$

For normal adult males the correspondence is not so close.

$$d = -0.32 \text{ mm.}$$

For a strict comparison we should take the standard variation (σ) for the measurements of the same fifty casts; but the above serves to show that, while the differences are very small, they are in the same sign, and indicate, if anything, a slight increase in the range of values. Presumably this is due to the error of the part measurements as contrasted with the single measurements of the whole line. While d will not account for all the differences between the two halves of the palate, it demands a further reduction of what is already within the bounds of the accidental. Thus we have gained one point; viz., that the median plane as defined by the points A', A'', C', can be assumed to lie between, and approximately equidistant from, A' and A''.

As the first molar is firmly seated before the other permanent teeth appear, and as the canines come very late, we should expect crowding of the teeth to affect the canines most of all. While this would greatly increase the variability of the width at the canines, there is no reason for supposing that the displacement would be constantly greater on one side of the jaw than on the other. In this connection we made a few trial measurements, and found the tendency toward symmetry constant. From all this we feel justified in assuming the form of the palate as defined by the teeth to approximate symmetry.

Returning to the consideration of the type of the palate for normal adult males, and proceeding upon the assumption of a symmetrical type, that measurements for the other teeth may be taken from C'' as a fixed point. For example, the second molar has

$$[C'C''] = 38.04 \text{ mm.}$$

The first molar has

$$[C'C''] = 28.71 \text{ mm.}$$

Can we assume that, if the palates are superimposed with respect to the first molars, the second molars will also be superimposed with a minimum difference? It is obvious that, if the type is symmetrical, the adjustment of

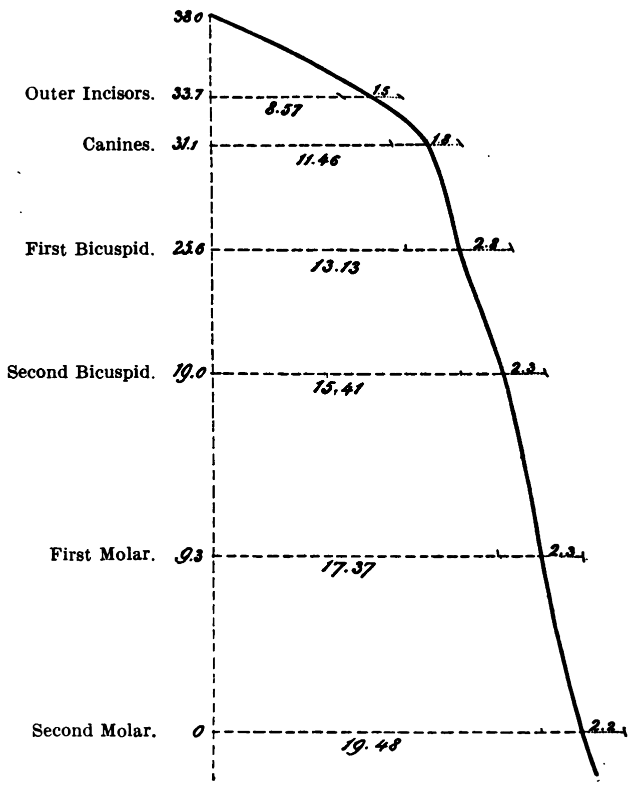

Fig. 3. Type of Palate as determined for the Normal-minded. Measurements given in millimetres.

one point must approximate all other points; but, since every known point is a variable, the selection of any one point as the initial point of regard is arbitrary, and can give approximate results only. Yet the measurements of length ($C'C''$) in the tables represent separate determinations of C'' for each pair of teeth (points A', A''); and the [$C'C''$], or length, represents the location of C' with reference to C'' as a fixed point. Since the type is symmetrical, all the points C'' must fall in the same straight line, — the median axis of the palate. Thus the adjustments have been approximated in the measurements, and the projection of the plotted form from C'' represents the approximate superimposed type.

This type can be plotted as in Fig. 3. C'' for each tooth is given as located by the second molar. The irregular curved line represents the approximate form of the palate as defined by the teeth and the gum-line. The small numerals outside of this curve, and the corresponding marks on the ordinate, indicate the variability of the normal palate as expressed by σ, the limits within which about seventy per cent of all normal cases will fall. The range of the alveolar point may be determined from σ for lengths in Table I.

It may be noted that the indicated variability from the type-curve decreases as the alveolar point is approached; but this is more apparent than real. The geometric relations are such that, as C'' approaches C', the standard variation of $C'C''$ decreases. The values of σ in Table I decrease constantly from 2.98 to 1.06. It will be observed that the same relation holds for σ of the points A''. This can be stated in general terms as a decrease in the absolute magnitude of the variation as we approach the alveolar point. For this reason we have not indicated graphically the range of the point C', but it will be observed that it varies in about the same degree as the point A''.

The net result of our inquiry, so far, is the approximation of the type of the normal adult male palate as expressed by the curves of the teeth. The curve that will best express the limits as graphically represented is the type. While the number of cases upon which this determination is based is approximately a hundred, the magnitude of the largest probable error is little more than the minimum unit of measure. With four hundred cases at our disposal, the result would be twice as exact, an accuracy meaningless from the practical point of view.

Type of Palate for the Feeble-minded. — In the previous discussion we have shown that, in the measurements from the first molars, there are no significant differences in symmetry between the normal and feeble-minded adult males. We may now proceed to a direct comparison of measurements.

The inner widths for feeble-minded adult males are as follows: —

	n	A mm.	$\pm\sigma$ mm.	$\pm\epsilon$ mm.
Outer incisors	–	–	–	–
Canines	124	22.36	±2.61	±0.23
First bicuspids	83	24.94	±3.10	±0.36
First molars	125	33.77	±3.61	±0.32
Second molars	71	38.80	±3.90	±0.46

For comparison let us take the measurements at the first molars. As previously stated, this measurement for adult normal males is as follows: —

	n	A mm.	$\pm\sigma$ mm.	$\pm\epsilon$ mm.
Normal-minded adult males	126	34.75	±3.35	±0.30
Feeble-minded adult males	125	33.77	±3.61	±0.32

The difference between the averages for the two classes of adult males is 0.98 mm. Then

$$(A_1-A_2) = 0.98$$
$$\sqrt{\epsilon_1^2+\epsilon_2^2} = \pm\ 0.44$$

Thus 0.98 ± 0.44 mm. expresses the range of the difference that must be allowed for accident or normal variation.

At the canines the differences in widths are as follows: —

	n	A mm.	$\pm\sigma$ mm.	$\pm\epsilon$ mm.
Normal-minded adult males	112	23.00	±2.24	±0.21
Feeble-minded adult males	124	22.36	±2.61	±0.23

$$(A_1-A_2) = 0.64$$
$$\sqrt{\epsilon_1^2+\epsilon_2^2} = \pm\ 0.31$$

At the first bicuspid

$$(A_1-A_2) = 1.32$$
$$\sqrt{\epsilon_1^2+\epsilon_2^2} = \pm\ 0.55$$

At the second molar

$$(A_1-A_2) = 0.16$$
$$\sqrt{\epsilon_1^2+\epsilon_2^2} = \pm\ 0.57$$

In no case are the above differences as much as three times the magnitude of the variabilities of the average: hence they may be construed as accidental.

The fact that these differences tend in the same direction (i.e., smaller values for the feeble-minded males) may be indicative of a slight difference, but too small to warrant consideration.

The measurements for the length from first molar forward, as $C'C''$, are as follows: —

	n	A mm.	$\pm\sigma$ mm.	$\pm\epsilon$ mm.
Normal-minded adult males . . .	104	28.37	±2.39	±0.23
Feeble-minded adult males . . .	112	29.50	±4.27	±0.40

$$(A_2 - A_1) = 1.13$$

$$\sqrt{\epsilon_1^2 + \epsilon_2^2} = \pm 0.46$$

Difference

$$1.13 \pm 0.46$$

This is a result similar to the foregoing, except that the relations are reversed; the feeble-minded males having the longer palate. However, the whole can be accounted for as accidental.

In conclusion it seems reasonable to assume that, if the measurements upon the palates of feeble-minded individuals agree with the type in the normal-minded in several dimensions, they will agree in all, and that no real differences in the curve of the palate can be found.

Height of the Palate. — There is another direction in which measurements are necessary,— the height or depth of the cavity known as the "roof of the mouth." In the foregoing measurements we adjusted the casts so that the points A', A'', and C', were in the same horizontal plane. For each value of $C'C''$ a new adjustment was made. It is now in order to consider the question as to the coincidence of these planes. If it is true that the gum-line and masticatory surfaces of teeth, or both, tend to a horizontal plane, our method of procedure will be greatly simplified. That the masticatory surfaces of the teeth present an approximately horizontal plane can be demonstrated by applying the casts to a plane surface; but, since we have chosen to use the gum-line as the point of departure for measurements in the horizontal plane, the relation of the two planes must be defined. For clearness we have measured a normal adult male palate so as to give the data for constructing a cross-section in the median plane. The following are the ordinates as measured from the two planes: —

	Plane of Mastication. mm.	Gum-line. mm.	Differences. mm.
Outer incisors	4	0	4
Canines	6	1	5
First bicuspids	10	5	5
Second bicuspids	15	10	5
First molars	18	13	5

These values with the position of the teeth in median plane give us the curve in Fig. 4.

Here we see that the gum-line and the masticatory surfaces are approximately parallel. Of course there is some variation, but it is so small that it cannot be measured unless we use more refined methods. As stated

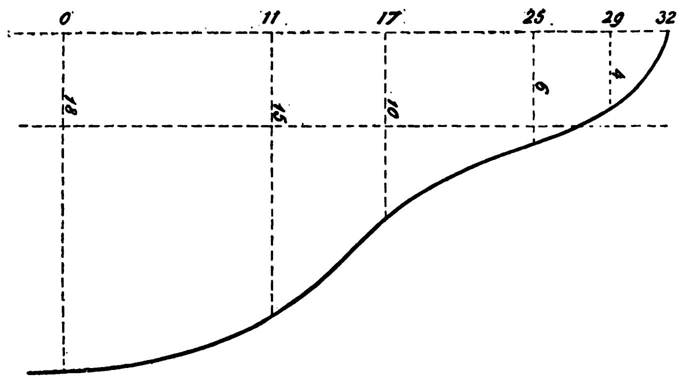

Fig. 4. Diagram for Heights of Palate.

previously, it was not practicable or necessary to measure in units less than one millimetre. Now we find that this measurement varies entirely within those limits, and may be taken as constant.

For a test-case we took ten casts, some of which had extreme irregularities of the gum-line, and measured the distance between the masticatory surface of the teeth and the gum-line at three points. The result was as follows: —

	Alveolar Point.	Canines.	First Molar.
	mm.	mm.	mm.
	5.0	5.5	4.5
	3.0	3.0	3.0
	5.5	6.0	4.0
	4.0	5.0	5.0
	4.0	4.0	4.0
	5.0	5.0	5.0
	2.0	4.0	6.0
	5.0	5.0	4.0
	5.0	5.0	5.0
	4.0	4.0	4.0
Total	42.5	46.5	44.5
Average	4.25	4.65	4.45

Considering that the above are in some ways unfavorable groups, we are safe in assuming that these two planes tend to be parallel, and that their standard variability is very small indeed. If the cast is adjusted to the approximate plane of the teeth, we shall also have the plane of the gum-line. The apparatus used in this research enabled us to adjust the casts in this dimension with accuracy, as repeated trials have shown. Thus we can proceed to the height of the palate.

The measurements upon the palate given above may also be used in plotting longitudinal sections. For comparative purposes any ordinate of the longitudinal section might be selected as the index of the height. We tried the maximum ordinate in the median plane and the maximum ordinate for the entire area anterior to the first molars. We shall not trouble the reader with the figures, because the comparative differences were small. We find, however, that the latter, the maximum height of the palate, can be measured with greater accuracy than the others: hence all the measurements are the maximum height.

We shall not at this time take up the definition of the type-contour of the cavity of the palate in the detailed way in which we worked out that for the teeth and the maxillary process, but pass the whole matter on with a statement of the values of the maximum heights.

MAXIMUM HEIGHT OF THE PALATE.

	n	A mm.	$\pm\sigma$ mm.	$\pm\epsilon$ mm.
Normal-minded adult males . . .	112	16.00	±2.31	±0.22
Feeble-minded adult males . . .	112	16.09	±2.63	±0.25

$$(A_2 - A_1) = 0.09$$

$$\sqrt{\epsilon_1^2 + \epsilon_2^2} = \pm\ 0.33$$

Difference

$$0.09 \pm 0.33.$$

Tabulation of Measurements. — We are now in a position to take up the question as to what measurements shall be selected for our comparison of palate-forms as to sex and physiological condition. The statement at the beginning, that there were no apparent differences in the results whether the size of the teeth was regarded or disregarded, must be taken with reference to the range of variability. Since the teeth are the only definite points for determining the palates of the living, they must form the point of departure in every case. For reasons previously stated, we have decided to use measurements from the inner surface of the teeth. Now we must decide upon the points taken for comparison. In the first place the first molar recommends itself because of its early eruption and the definiteness of the lateral fissure as a point from which to measure. In the second place the canines deserve consideration. While they are not so clearly defined at the gum-line, they erupt late in life and are especially liable to displacement by abnormalities of the jaw or over-large teeth. Though this is simply an assumption, it seems advisable to make the choice upon it; for, if there is a retardation of the physical development of idiots as a class, greater variation in the widths at the canines should be in evidence. However, there is another consideration: reference to Table I indicates greater variability in the measurements for the bicuspids in inner widths as compared to outer widths; and finally, the canines, as according to the type (Fig. 3), are situated at the greatest turning-point in the curve. For these reasons we have decided to subject all the casts at our disposal to four measurements, — widths at the canines and the first molars, and the respective distances to the alveolar point. The methods of measurement have been stated. We give at this time complete tables of these measurements (Tables IV and V). Here the ages, sexes, number of individuals, average measurements, and standard deviations are given. More complete tables, in which the entire distribution of the individual measurements will be found, are added, that the data may be serviceable for comparative and general statistical work (Tables VI–IX).

TABLE IV. MEASUREMENTS FOR NORMAL-MINDED INDIVIDUALS.

	Length of Palate.						Width of Palate at Canines.					
	Male.			Female.			Male.			Female.		
Age	*n*	Av. mm.	σ mm.	*n*	Av. mm.	σ mm.	*n*	Av. mm.	σ mm.	*n*	Av. mm.	σ mm.
6	15	29.73	2.71	38	29.08	1–65	16	23.00	1.87	46	21.30	1.96
7	25	30.86	3.07	36	29.91	1.72	27	22.37	1.86	38	22.50	2.32
8	27	31.15	2.86	29	30.93	2.17	26	23.61	2.15	31	23.00	2.25
9	36	31.16	3.27	43	31.65	2.15	35	23.67	1.96	43	23.60	2.02
10	30	31.33	2.91	34	30.85	2.12	30	24.13	2.28	34	23.70	2.17
11	22	30.77	1.65	31	31.54	2.98	21	24.33	2.17	31	23.48	2.07
12	21	23.98	3.21	23	31.13	2.02	21	23.43	2.80	23	24.17	2.41
13	12	30.75	3.43	16	30.87	3.31	11	23.09	1.48	15	23.20	2.26
6–13	188	30.68	3.05	250	30.70	2.34	187	23.57	2.31	261	22.98	2.22
21+	104	28.37	2.39	48	29.09	2.55	112	23.00	2.24	50	22.14	1.65

TABLE IV (*Concluded*).

	Width of Palate at First Molar.						Height of Palate.					
	Male.			Female.			Male.			Female.		
Age	*n*	Av. mm.	σ mm.	*n*	Av. mm.	σ mm.	*n*	Av. mm.	σ mm.	*n*	Av. mm.	σ mm.
6	16	32.00	2.33	39	32.28	2.13	16	12.50	1.32	39	11.33	1.60
7	25	32.84	1.75	36	32.36	2.65	26	12.80	1.61	35	11.88	1.65
8	29	32.88	2.54	31	32.54	2.43	26	11.88	1.51	29	12.41	1.47
9	37	33.03	2.60	43	33.14	2.28	34	12.35	1.96	43	12.97	1.83
10	31	32.80	2.32	33	32.27	2.48	31	11.48	1.66	34	12.02	1.58
11	26	33.69	2.27	31	33.35	2.13	22	12.04	1.76	31	12.51	2.07
12	16	31.87	2.81	23	33.47	2.28	21	12.42	1.93	23	12.39	2.32
13	12	33.33	3.18	16	33.93	1.87	12	11.50	1.82	16	13.12	2.08
6–13	192	32.92	2.28	252	32.81	2.35	188	12.14	1.75	250	12.31	1.96
21+	126	34.75	3.35	49	34.00	3.36	112	16.00	2.31			

TABLE V. MEASUREMENTS FOR FEEBLE-MINDED INDIVIDUALS.

	Width of Palate at First Molar.						Height of Palate.					
	Male.			Female.			Male.			Female.		
Age	*n*	Av. mm.	σ mm.	*n*	Av. mm.	σ mm.	*n*	Av. mm.	σ mm.	*n*	Av. mm.	σ mm.
6	2	–	–	4	–	–	2	–	–	6	–	–
7	5	–	–	4	–	–	5	–	–	4	–	–
8	17	33.94	2.43	14	30.42	3.10	17	12.61	2.16	13	13.23	2.61
9	16	34.68	2.01	11	32.36	2.65	16	12.19	2.34	11	13.00	1.12
10	31	33.77	2.86	14	32.85	2.35	32	14.43	1.93	14	12.00	1.96
11	40	34.00	3.43	20	32.15	2.77	39	13.69	2.01	18	12.50	1.66
12	44	33.66	3.71	24	32.54	3.32	42	13.90	2.31	25	12.85	2.41
13	20	33.06	3.72	32	32.81	2.16	21	13.00	2.37	32	13.53	2.26
6–13	175	33.86	3.01	123	32.25	2.63	174	13.39	2.28	123	12.96	2.05
14	53	33.28	3.56	38	33.71	3.32	51	13.13	2.68	38	13.58	2.30
15	37	34.29	3.48	33	32.78	4.20	37	14.24	2.97	33	14.78	2.36
16	43	34.65	2.41	37	32.59	3.07	42	13.92	2.67	37	14.13	2.40
17	37	33.25	3.31	25	32.80	3.05	36	14.55	2.60	25	15.64	1.92
18	34	34.76	3.31	28	32.18	3.28	34	15.55	2.90	28	15.47	2.71
19	17	35.64	2.86	27	32.11	3.00	17	15.41	2.50	27	15.59	2.65
20	37	35.75	3.92	23	32.86	3.46	36	16.00	2.08	20	14.95	2.56
14–20	258	34.29	3.55	211	32.77	3.19	253	14.35	2–76	208	14.76	2.51
21+	125	33.77	3.61	115	33.28	3.08	112	16.09	2.63	115	14.87	2.66
Total	558	34.04		449	32.80							

TABLE V (*Concluded*).

	Length of Palate.						Width of Palate at Canines.					
	Males.			Females.			Males.			Females.		
Age	*n*	Av. mm.	σ mm.	*n*	Av. mm.	σ mm.	*n*	Av. mm.	σ mm.	*n*	Av. mm.	σ mm.
6	1	–	–	4	–	–	2	–	–	6	–	–
7	3	–	–	4	–	–	5	–	–	4	–	–
8	14	31.15	2.01	14	29.78	–	17	22.17	2.31	14	22.64	2.45
9	16	31.00	2.81	11	32.30	–	16	24.93	3.48	11	23.27	1.90
10	32	31.59	2.61	14	30.00	–	32	24.84	3.66	14	22.50	2.13
11	39	31.46	3.21	20	30.45	2.23	40	23.32	1.87	20	21.75	2.33
12	43	32.11	3.18	23	30.82	3.30	44	23.25	2.77	25	22.96	2.35
13	21	31.33	3.25	32	30.53	2.87	21	23.66	3.48	33	23.03	2.46
6–13	169	31.36	3.09	122	30.59	2.65	177	23.53	3.01	127	22.68	2.36
14	54	31.27	2.91	38	28.63	2.85	53	23.66	2.65	38	23.10	1.97
15	35	30.00	2.07	32	29.03	2.22	37	23.89	2.15	33	21.60	3.43
16	42	29.47	3.35	36	29.63	2.32	42	23.83	2.28	37	22.00	3.10
17	37	30.16	2.66	24	29.04	2.33	36	22.44	2.53	24	21.75	2.28
18	34	29.44	2.38	28	29.89	2.70	34	22.94	2.68	28	21.57	2.63
19	16	28.81	2.32	27	28.22	3.01	16	23.50	2.50	27	20.88	2.72
20	36	30.83	2.80	21	30.53	3.42	35	23.51	3.20	23	21.95	2.33
14–20	254	30.32	2.83	206	29.01	2.68	253	23.34	2.89	210	21.77	2.52
21+	112	29.50	4.27	102	28.67	3.05	124	22.36	2.61	115	21.67	2.89

TABLE VI. DISTRIBUTION OF CASES, WIDTH AT FIRST MOLARS.

Condition.	Feeble-Minded.						Normal-Minded.			
Age	6–13		14–20		21 +		6–13		21 +	
Sex	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.
mm.										
22	–	–	2	–	–	–	–	–	–	–
23	–	–	1	3	–	–	–	1	–	–
24	1	–	0	3	–	–	–	–	–	–
25	1	3	1	1	1	1	2	0	–	–
26	2	1	0	3	4	2	1	1	–	1
27	2	1	4	7	1	2	2	2	–	1
28	1	5	6	4	5	3	5	4	1	0
29	5	6	7	12	6	6	3	16	6	2

TABLE VI (*Concluded*).

Condition.	Feeble-Minded.						Normal-Minded.			
Age	6–13		14–20		21 +		6–13		21 +	
Sex	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.
mm.										
30	10	16	14	14	10	9	16	16	6	3
31	14	15	11	22	8	9	20	27	9	6
32	19	25	25	17	7	9	30	48	12	2
33	21	8	25	34	11	20	41	40	11	6
34	17	17	33	29	16	11	32	34	9	6
35	26	12	32	24	15	17	17	28	17	5
36	25	6	37	14	12	6	11	22	21	5
37	13	4	21	6	12	12	6	8	13	6
38	12	2	14	8	8	2	1	2	5	2
39	4	2	11	5	3	5	3	3	6	3
40	1	–	7	3	3	0	0	–	4	0
41	0	–	1	2	0	0	0	–	4	1
42	1	–	3	–	1	1	0	–	0	–
43	–	–	2	–	1	–	2	–	1	–
44	–	–	0	–	0	–	–	–	0	–
45	–	–	1	–	–	–	–	–	0	–
46	–	–	–	–	1	–	–	–	1	–
Total	175	123	258	211	125	115	192	252	126	49

TABLE VII. DISTRIBUTION OF CASES, HEIGHT OF PALATE.

Condition.	Feeble-Minded.						Normal-Minded.		
Age	6–13		14–20		21 +		6–13		21 +
Sex	M.	F.	M.	F.	M.	F.	M.	F.	M.
mm.									
4	–	–	–	–	–	–	–	1	–
5	–	–	1	–	–	–	–	0	–
6	1	–	3	1	–	–	–	0	–
7	0	–	0	0	1	1	–	0	–
8	3	2	1	2	1	1	–	2	–
9	4	6	3	4	0	1	7	11	–
10	9	6	7	7	0	2	30	28	1
11	18	18	20	11	3	8	33	48	1
12	29	25	23	7	8	11	44	52	4

TABLE VII (*Concluded*).

Condition.	Feeble-Minded.						Normal-Minded.		
Age	6–13		14–20		21+		6–13		21+
Sex	M.	F.	M.	F.	M.	F.	M.	F.	M.
mm.									
13	28	23	32	30	5	11	35	47	11
14	28	18	36	29	8	18	19	23	13
15	24	9	37	36	18	14	15	25	16
16	13	7	29	33	17	16	3	8	18
17	9	5	28	16	18	9	1	3	19
18	2	3	18	16	14	15	1	0	12
19	5	1	10	9	9	3	–	1	10
20	0	–	2	4	3	3	–	0	5
21	1	–	1	3	5	1	–	1	1
22	–	–	1	–	1	0	–	–	0
23	–	–	0	–	0	0	–	–	0
24	–	–	0	–	1	1	–	–	1
25	–	–	1	–	–	–	–	–	–
Total	174	123	253	208	112	115	188	250	112

TABLE VIII. DISTRIBUTION OF CASES, LENGTH OF PALATE.

Condition.	Feeble-Minded.						Normal-Minded.			
Age	6–13		14–20		21+		6–13		21+	
Sex	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.
mm.										
18	–	–	–	–	1	–	–	–	–	–
19	–	–	–	–	0	–	–	–	–	–
20	–	–	–	–	2	–	–	–	–	–
21	1	–	1	–	2	1	1	–	–	–
22	1	1	1	–	0	0	0	–	2	1
23	2	0	1	2	4	2	1	1	1	0
24	0	1	4	4	4	4	1	1	2	2
25	0	2	11	12	5	8	6	1	3	3
26	8	6	7	16	8	11	4	6	11	4
27	4	7	11	24	10	13	15	9	18	6
28	11	8	24	23	15	9	17	18	18	9
29	15	12	33	32	12	12	21	44	15	9
30	25	17	45	29	8	15	24	41	8	6

TABLE VIII (*Concluded*).

Condition.	Feeble-Minded.						Normal-Minded.			
Age	6–13		14–20		21 +		6–13		21 +	
Sex	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.
mm.										
31	20	24	40	24	8	8	23	39	12	1
32	25	16	18	17	9	9	21	36	5	3
33	18	13	19	7	3	5	19	26	6	2
34	12	7	22	9	6	2	16	14	3	1
35	13	4	9	4	5	2	10	19	–	1
36	3	2	3	1	1	1	4	2	–	–
37	3	1	2	2	3	–	3	1	–	–
38	6	1	0	–	2	–	2	1	–	–
39	2	–	1	–	3	–	–	1	–	–
40	–	–	2	–	0	–	–	–	–	–
41	–	–	–	–	1	–	–	–	–	–
Total	169	122	254	206	112	102	188	250	104	48

TABLE IX. DISTRIBUTION OF CASES, WIDTH AT CANINES.

Condition.	Feeble-Minded.						Normal-Minded.			
Age	6–13		14–20		21 +		6–13		21 +	
Sex	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.
mm.										
9	–	–	–	–	–	–	–	–	1	–
10	–	–	–	–	–	1	–	–	0	–
11	–	–	–	–	–	1	–	–	0	–
12	–	–	–	1	–	0	–	–	0	–
13	–	–	1	2	–	0	–	–	0	–
14	1	–	0	0	–	0	–	–	0	–
15	1	1	2	1	1	2	–	–	0	1
16	1	0	2	5	2	2	–	1	0	0
17	3	1	4	4	1	4	1	2	2	0
18	5	6	3	7	4	3	0	2	2	1
19	6	3	3	16	9	8	5	10	4	1
20	7	9	16	17	14	10	10	25	8	4
21	13	17	22	31	11	25	18	26	10	7
22	23	22	37	33	21	17	25	37	18	16
23	30	20	32	30	19	10	35	56	22	7

.TABLE IX (*Concluded*).

Condition.	Feeble-Minded.						Normal-Minded.			
Age	6–13		14–20		21+		6–13		21+	
Sex	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.
mm.										
24	25	19	50	31	15	13	39	40	19	10
25	19	13	36	22	12	7	22	25	16	3
26	20	11	24	4	9	7	17	15	5	–
27	10	4	7	3	6	3	7	11	1	–
28	2	1	7	2	–	2	2	7	0	–
29	4	–	4	1	–	–	2	2	2	–
30	3	–	2	0	–	–	0	1	0	–
31	1	–	0	–	–	–	2	–	1	–
32	2	–	0	–	–	–	0	–	1	–
33	0	–	0	–	–	–	0	–	–	–
34	1	–	1	–	–	–	1	–	–	–
35	–	–	–	–	–	–	0	–	–	–
36	–	–	–	–	–	–	1	–	–	–
Total	177	127	253	210	124	115	187	260	112	50

In order to make clear some of the more technical aspects of the foregoing data, we have selected palates of feeble-minded adult males from nineteen to twenty years of age, taken independently, for the respective measurements, so as to show the average dimensions, the two extremes, and $A \pm \sigma$. Bearing in mind that about seventy per cent of all cases will fall between $-\sigma$ and $+\sigma$, the plates will give a fair idea of the relative appearances of the casts. The palates shown in Plate XIV were selected according to the width at the first molars; those in Plate XV, according to the height of palate; those in Plate XVI, according to the length of palate; and those in Plate XVII, according to the width at the canines. Finally three palates were selected that conform approximately to the average type in all the measurements made, and these are shown in Plate XVIII. The photographs were taken with approximately the same distance from the plates to the objects. We believe that these plates will show how difficult it is to judge the dimensions of the palate by the eye.

In viewing the plates, it may be well to note that they have the following respective values in reading order,— the minimum, the average less σ, the average, the average plus σ, and the maximum of the series as measured. In Plate XVIII the palates have the four dimensions approximating each, the averages less the σ's, the averages, and the averages plus the σ's.

Growth of the Palate. — The growth of the hard palate and the maxillary process must receive some attention; for upon *a priori* grounds an arrested or perverted development of a morphological unit must take its departure from some point in the formative process. Unfortunately the limitation of our material does not permit of our investigations during the period of infancy. We cannot take up the problem until the permanent teeth erupt. For the feeble-minded, we have no data for individuals before the age of eight years: indeed, the number of cases for all ages below ten years is so small, that our series must necessarily begin at that point. In the normal series we can begin with the seventh year. It will be observed that the number of cases for each age is small, — so small, that, taking each by itself, nothing could be determined. The fact that we have the successive ages enables us to use one as a check upon the other, since the variations due to accidental cases will tend to balance in the series of age-averages. Upon this basis it is possible to reach a satisfactory conclusion.

As we have previously determined the type for normal adult males, let us proceed to normal male children. Tables IV and V give us at once the averages and standard variations for each age in the four definitive measurements. Let us begin with the width at the first molars. Inspection makes it clear that no important difference will be found, since the minimum value occurs at the age of twelve and the maximum at eleven. If we choose the general average of the widths for all male children (32.92 mm.) as the median point for the series of age-averages, we get the following array of differences: —

Age.	Differences. mm.	Age.	Differences. mm.
6	− .92	10	− .12
7	− .08	11	+ .77
8	− .04	12	− .05
9	+ .11	13	+ .41

In two cases the difference is approximately zero, while the remaining are equally divided as to positive and negative. The maximum difference is about one millimetre. Taking the figures alone, it is apparent that we are not justified in assuming any appreciable increase in width between the ages of six and thirteen.

Normal female children may be used in this connection. The general average for all ages is 32.81 mm. The differences are: —

Age.	Differences. mm.	Age.	Differences. mm.
6	−0.53	10	− 0.54
7	−0.45	11	+0.54
8	−0.27	12	+0.66
9	+0.33	13	+1.12

While the differences are small, they present a regularity of distribution as to positive and negative that resembles growth, because the values are uniformly lower at the beginning, and higher at the end. Yet the maximum difference for the whole series is but 1.66 mm. Thus the measurements of male and female children lead to the same conclusion; viz., that while there is evidence of growth in the width at the first molars, the increment is so small that it may be assumed inappreciable between the ages of six and thirteen.

When these results are compared with those for adult normal males, we find evidence of growth. Taking the average for adults (34.75 mm.) as the point of departure, we find the following differences for male children: —

Age.	Differences.	Age.	Differences.
	mm.		mm.
6	−2.75	10	−1.95
7	−1.91	11	−1.06
8	−1.87	12	−2.88
9	−1.72	13	−1.42

To this there is but one interpretation, — the widths at the first molars are greater for adults than for children under twelve years of age. The average of all children as opposed to adults has a probability as follows: —

$$(A_1 - A_2) = 1.83 \text{ mm.}$$
$$\sqrt{\epsilon_1^2 + \epsilon_2^2} = \pm\ 0.33 \text{ mm.}$$

The difference 1.83 ± 0.33 mm. is about 5.6 σ, or a certain difference. However, the absolute increment is so small that we must give this point further consideration.

We have no casts for normal children over thirteen years of age, the period during which there is an apparent growth; but we have casts for these years in the feeble-minded series. By introducing the whole feeble-minded series we may be able to reach a satisfactory result. We have plotted the successive average for all ages on a magnified scale, as shown in Fig. 5. Here we see a tendency for the curves for normal children to rise, but they fail to reach the adult level. The curves for feeble-minded children are less regular, but the number of cases for eight and nine years is small. The extreme values for feeble-minded males at nineteen and twenty years cannot be accounted for at this time. When the average for adult feeble-minded males is considered, it appears that the male children approximate this level, since the variations are about equally numerous in either direction. The female children present an extreme variation at the eighth year, but in other respects approximate the adult level. We have previously shown that the differences between normal and feeble-minded male adults can be accounted for as accidental; and, applying the same scale to our graphic form, we can safely assume that, for feeble-minded children over nine years of age, there is approximately no growth in the width of the palate at the

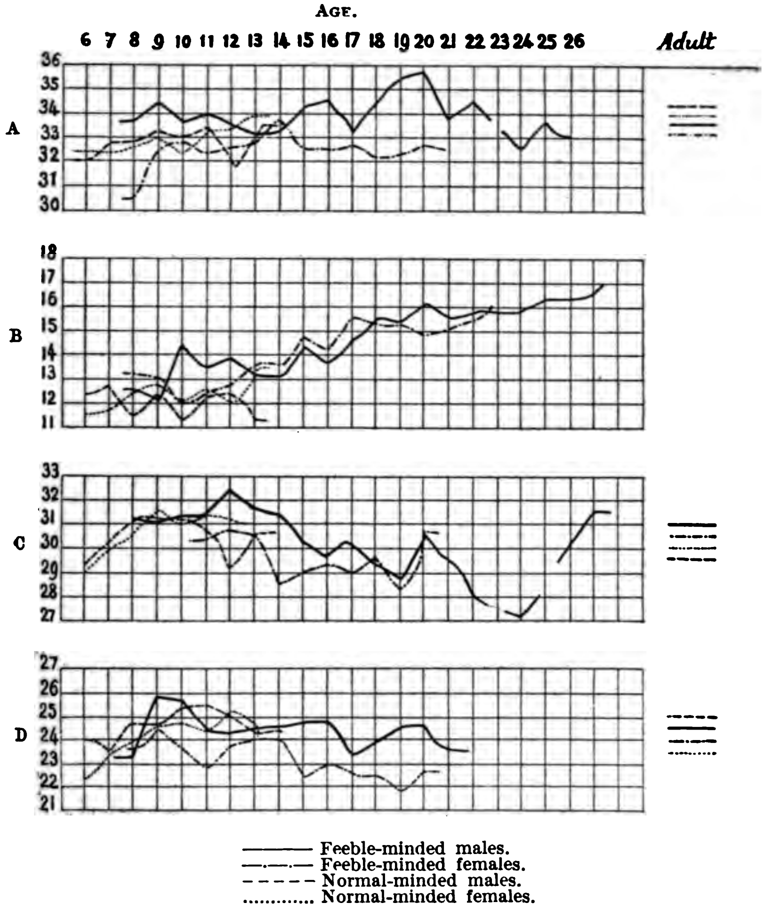

Fig. 5. Diagram showing Measurements for Various Ages. A, molar width; B, height of palate; C, length of palate; D, canine width.

first molar. For normal children some growth is evident; but the annual increments are too small to be measured satisfactorily.

The width at the canines also deserves our attention. It is apparent that there is a close agreement between the averages for children and adults. For normal children we find the following differences from their general average: —

Age.	Male Differences. mm.	Female Differences. mm.	Age.	Male Differences. mm.	Female Differences. mm.
6	−0.57	−1.60	10	+0.56	+0.72
7	−1.20	−0.48	11	+0.76	+0.50
8	+0.04	+0.02	12	−0.14	+1.19
9	+0.10	+0.62	13	−0.48	+0.22

There is an apparent tendency toward higher averages at from nine to eleven years of age. For feeble-minded females the differences from the total average of 22.30 mm. are as follows: —

Age.	Differences. mm.	Age.	Differences. mm.
8	+0.34	15	−0.70
9	+0.97	16	−0.30
10	+0.20	17	−0.55
11	−0.55	18	−0.73
12	+0.66	19	−1.42
13	+0.73	20	−0.45
14	+0.80	21+	−0.63

This series brings out emphatically the peculiar increase in width to the fourteenth year and the subsequent decline toward maturity. From the curves (Fig. 5) it is obvious that all tend to do the same. If, however, we take the average for females thirteen years of age, we find it differing from the average for adult females as follows: —

$$(A_1 - A_2) = 1.36 \text{ mm.}$$
$$\sqrt{\epsilon_1^2 + \epsilon_2^2} = \pm\, 0.51 \text{ mm.}$$

This is within the limits of accident. The same can be said of the other differences, so that this apparent tendency must receive its validity from the uniformity of the results alone.

Thus our general conclusion is, that there is no evidence of growth in the width of the palate at the canines after the eighth year of life.

The length of the palate as measured from the first molars presents a series of changes similar to those for the canine widths. The curves suggest a decrease in the measurement with increasing age. For normal male children and adults the differences are: —

$$(A_1 - A_2) = 2.31 \text{ mm.}$$
$$\sqrt{\epsilon_1^2 + \epsilon_2^2} = \pm\, 0.32 \text{ mm.}$$

A difference of 2.31 ± 0.32 is a certain difference. For feeble-minded males (children and adults) the difference is 1.86 ± 0.46, also approximately certain. On the other hand, the difference between normal and feeble-minded male children is within the range of accident. When females are examined, the differences as to age are in the same direction, but of less magnitude.

Taking the adult feeble-minded as the point of departure, we then have the following differences: —

Age.	Male Differences. mm.	Female Differences. mm.	Age.	Male Differences. mm.	Female Differences. mm.
8	+1.65	+1.11	15	+0.50	+0.36
9	+1.50	+3.63	16	−0.03	+0.96
10	+2.09	+1.33	17	+0.66	+0.37
11	+1.96	+1.78	18	−0.06	+1.22
12	+2.61	+2.15	19	−0.69	−0.45
13	+1.83	+1.86	20	+1.33	+1.86
14	+1.77	−0.04	21+	0.00	0.00

While the decrease of measurement in the width of the canines could be explained by accident, the changes in the above series cannot be so interpreted. The maximum length seems to occur at from twelve to thirteen years of age. Thus we have a change of measurement concomitant with age. Since this change is in the reverse order of growth, it demands explanation. This we shall consider later.

The height of the palate as measured shows decided increase with age. The difference between normal male children and adults is 3.86 ± 0.27 mm., or fourteen times the range for accident. On the other hand, there is no good evidence for growth between the ages of six and thirteen. From the curves (Fig. 5) the increase seems to set in at the twelfth year. The curves for all sexes and conditions seem to hold the same level from six to twelve years of age. While a general increase is apparent, the annual increment is so small and the number of cases so limited, that the annual differences are not uniformly positive, as they should be in normal growth, as may be seen from the following: —

Age-Interval.	Males. mm.	Females. mm.	Age-Interval.	Males. mm.	Females. mm.
8–9	−0.42	−0.23	15–16	−0.32	−0.65
9–10	+2.24	−1.00	16–17	+0.63	+1.51
10–11	−0.74	+0.50	17–18	+1.00	−0.17
11–12	+0.21	+0.35	18–19	−0.14	+0.12
12–13	−0.90	+0.68	19–20	+0.59	−0.64
13–14	+0.13	+0.03	20–21+	+0.09	+0.11
14–15	+1.11	+1.20			

If two-year intervals are taken, the differences become positive after the thirteenth year: hence there is a positive annual increase. The point of interest is, that the change in the height of palate occurs after the twelfth or thirteenth year.

To sum up, we find no increase in the width at the canines after the eighth year, and probably not after the eruption of the first permanent molars. The width at the first molars for feeble-minded children is practically fixed at the age of nine: for normal children, the limits may be reached a little later, though the differences are very small. The height of the palate increases about one-fourth between the ages of twelve and twenty-one. The length of the palate as measured shows a marked decrease from twelve years to maturity. It remains to discuss these results.

Dentition. — One of the chief objections to the foregoing conclusions will be that we have disregarded the effects of dentition. That changes in the teeth will modify measurements seems probable. Whether the permanent teeth change the form of the alveolar process and also the palate is a matter concerning which there seem to be no available data. Indeed, data of any kind as to dentition are scarcely to be had. All of the books treating the subject contain general statements as to the probable time of the eruption of the teeth, but no detailed observations as to the variability in time. In a recent publication,[1] we brought together what data were available, and found them so meagre that the casts used in this research were drawn upon (Table X).

TABLE X. NUMBER OF CHILDREN HAVING PERMANENT TEETH.

Age.	Boys. Cases.	Inner Incisors.	Outer Incisors.	Canines.	Bicuspids.	First Molars.	Second Molars.	Girls. Cases.	Inner Incisors.	Outer Incisors.	Canines.	Bicuspids.	First Molars.	Second Molars.
6	23	7	1	–	–	15	–	46	18	4	3	7	38	1
7	30	12	2	1	1	25	–	39	31	11	1	16	36	–
8	27	22	7	–	5	27	–	31	26	15	3	14	29	2
9	40	39	27	–	12	40	3	42	42	25	4	19	42	1
10	33	33	21	11	22	33	1	34	32	28	5	25	34	3
11	21	21	20	13	21	21	2	30	29	29	22	25	30	6
12	21	21	21	18	21	21	8	22	22	22	19	22	22	7
13	12	12	12	11	12	12	8	16	16	14	14	16	16	11
14	12	12	12	12	12	12	9	9	9	8	8	9	9	8
15	–	–	–	–	–	–	–	7	7	7	7	7	7	7

For comparison we have tabulated the presence of the permanent canines and the second molars as shown by the casts for the feeble-minded.

[1] Statistics of Growth (Report of Commissioner of Education, 1904, p. 34).

TABLE XI. NUMBER OF OBSERVED CANINE AND MOLAR TEETH AMONG THE FEEBLE-MINDED.

Age.	Males.			Females.		
	Cases.	Canines.	Second Molars.	Cases.	Canines.	Second Molars.
8	17	1	1	14	5	0
9	16	3	5	11	1	1
10	32	13	6	14	10	4
11	40	20	15	20	9	4
12	43	37	19	25	18	6
13	21	18	14	34	32	28
14	53	43	41	38	31	36
15	37	32	35	33	32	32
16	43	39	38	35	34	35
17	37	35	36	24	24	24
18	34	34	32	–	–	–
19	12	12	12	–	–	–

As the tables stand, it is scarcely possible to compare them, since they do not give us the number of teeth erupted in a given year. To be intelligible we must translate the results into terms of a definite group of growing children. This is the same problem that confronts one in vital statistics when he wishes to know the distribution of deaths in a group of, say, a thousand persons. A fair approximation of this can be made by the use of the formula

$$l_2 = l - d\,\frac{l_1 + l_2}{2}$$

in which l represents the number living; d, the death-rate for the period; l_2 the number of survivals at the end of the period.[1] In our problem let l_1 = the number not having erupted teeth; d, the rate of eruption for the year; l_2, the number remaining without teeth at the end of the year. Taking a thousand feeble-minded children at seven years, we get the values in

[1] E. Dormay, Theorie mathematique des assurances sur la vie.

Table XII. These give us series expressing the variability in the eruption of the teeth. Unfortunately there are no data for the ages preceding eight, for the character of the distribution is such that cases are to be expected for six and seven years. Yet the number of such cases must be small, and their effect upon the average unimportant. Taking the series as they stand, we find the average ages to be:—

	Males.		Females.	
	Average years	σ years	Average years	σ years
Canines	10.7	±1.4	10.0	±1.7
Second molars	10.9	±1.9	11.8	±0.9

We may compare these averages with the corresponding values in the following table of average ages for the eruption of teeth among the normal-minded.[1]

	Boys.		Girls.	
	Average years	σ years	Average years	σ years
Inner incisors	7.5	1.4	7.0	1.6
Outer incisors	9.5	2.1	8.9	2.1
Bicuspids	9.8	1.6	9.0	2.8
Canines	11.2	1.4	11.3	1.0
Second molars	13.2	2.0	12.8	1.6

These averages and variabilities were calculated by a different method from that employed by us, but should be approximately equivalent to results obtained from our calculations. It will be observed that the average ages for the eruption of the teeth are higher among normal children. For the canines, the differences are 0.5 and 1.3 years; for the second molars, 2.3 and 1.0 years. The method by which the averages were obtained makes it difficult to estimate the importance of these differences. The number of cases for the successive ages varies to such a degree that it would be advisable to weight them accordingly. We have not done this, because we regard the nature of the material such that more than a tentative conclusion cannot be expected, and for the further reason that the differences found in the above are not great enough in themselves to warrant the assumption that they are significant, and not due to accident. With the casts there is some difficulty in distinguishing between temporary and permanent canines, and errors doubtless occurred in this way. This does not apply to the results for the

[1] Statistics of Growth (Report of the Commissioner of Education, 1904, p. 35).

TABLE XII. ESTIMATED ERUPTIONS OF CANINE AND MOLAR TEETH AMONG 1000 CHILDREN.

Age.	Canines.		Second Molars.	
	Males.	Females.	Males.	Females.
7	0	0	0	0
8	60	350	60	0
9	163	8	244	90
10	252	335	130	232
11	251	113	177	123
12	162	92	141	120
13	65	66	126	257
14	23	20	69	113
15	17	10	35	44
16	4	4	12	16
17	2	2	5	5
18	1	0	1	0
19	0	0	0	0
	1000	1000	1000	1000

second molars, for their presence can be definitely determined. If we consider the preceding tables, we have some reason for assuming that the feeble-minded erupt their permanent teeth sooner than normal children. The idea that they mature sooner than normal individuals is current, though supported by little statistical evidence. From what data we have, there is the suggestion that the feeble-minded show tendencies to retain their temporary teeth indefinitely, because it seems probable that, if an individual retains his first canines to the age of nineteen years, he will not erupt permanent canines. Yet we do not regard this as more than a suggestion. A systematic record of the dentition of the inmates of schools for the feeble-minded would add materially to our knowledge of the subject. Unfortunately no one has seen the importance of it.

To return to our problem. If there is a difference in the time of eruption, the same relation should appear in the series for the third molars. This is another case in which satisfactory data are wanting. From the casts we obtained the estimated eruptions in Table XIII.

TABLE XIII. ESTIMATED ERUPTIONS OF THIRD MOLARS AMONG 1000 PERSONS.

Age.	Normal-Minded Males.		Feeble-Minded Males.		
	Cases.	Third Molars.	Cases.	Third Molars.	Eruptions.
14	12	0	53	1	2
15	6	0	37	0	0
16	2	0	43	2	48
17	1	0	37	1	28
18	2	1	34	4	104
19	12	6	12	4	232
20	10	3	19	1	29
21	11	6	30	7	115
22	12	6	31	14	205
23	6	3	4	1	54
24	17	12	12	3	41
25	11	5	15	5	50
26	9	2	8	4	38
27	5	2	4	3	35
28	3	1	4	3	11
29	7	4	2	1	4
30	1	0	5	3	3
31	2	2	1	0	0
32	3	3	2	1	1
33	1	0	0	0	0
34	3	3	0	0	0
35	3	1	0	0	0
36+	14	10	0	0	0
Total	153	70	353	58	1000

The average age for the eruption of the third molars with the feeble-minded is 21.0 ± 2.9. It will be observed that the number of cases is insufficient for a comparison of the normal and feeble-minded series. We have but a few casts for normal males between the ages of fourteen and nineteen, and the number for the succeeding ages is so small that a restoration of the series by interpolation is scarcely worth while. It is interesting to observe that a considerable number of individuals seem to have failed to erupt their third molars.

The result of this comparison seems to be the indication of retarded dentition on the part of the feeble-minded, but the data are very unsatisfactory.

In the discussions of the changes in the width at the canines, it appeared that the maximum measurements occurred during childhood. From nine to ten years seems to be the maximum age for feeble-minded children, and we have just shown that the average age for the eruption of these teeth is from ten to eleven years. Other things being equal, the measurements would be greater for palate widths when the permanent teeth were erupting, because of the narrowness of their bases. For normal children, the maximum measurement occurs a year later; and the average age for the eruption of the canines is from eleven to twelve years. Thus we feel justified in assuming that this is the cause of the peculiar variation previously observed in the measurements for canine widths. In the same way, the eruption of the incisors may affect the measurements of length. As previously noted, the lengths are slightly greater in early life: for normal children, the maximum is reached at about the ninth year; for feeble-minded children, at about the twelfth. The number of young feeble-minded children is too small for us to calculate the average time for the eruption of the inner incisors; but the average for normal children is from seven to eight years. This agrees well with the maximum measurement at from eight to nine years. However, it is not clear that this is the cause of the variation, since there is a gradual decrease in the measurement with age. If there is an increase in the width at the first molar, even though slight, it may tend to compensate by shortening the length as measured in the approximate median plane. The fact is, however, that all these differences are exceedingly small; and that the phenomenon of eruption of the permanent teeth does not seriously modify the type in respect to the dimensions we have examined. We gave special consideration to the canines, because they are the last of the anterior teeth to erupt, and present the phenomenon of crowding in the extreme. If the typical width of the palate at the canines is not affected appreciably by this eruption, it seems reasonable to assume that the effect of eruption upon the form of the alveolar process and the dimensions of the hard palate can be disregarded.

That there is little or no growth in the anterior alveolar process after the seventh or eighth year of life is suggested by other data. A tabulation of head-measurements ranging from early childhood to maturity indicates very little growth in the size of the head as compared with the body.[1] Further, it has been generally assumed that the growth of the alveolar process is from behind. "In the young subject the alveolar arch describes almost the segment of a circle, but in the adult the curve is semi-elliptical. The increase which takes place in the length of the jaw arises from a growth

[1] Statistics of Growth (Report of Commissioner of Education, 1904, p. 26).

behind the position of the milk-teeth, so as to provide room for the three additional teeth on each side belonging to the permanent set."[1]

The casts for adults look larger than those for children, because of the greater number of teeth, the greater total length of the alveolar process, and the greater size of the permanent teeth. The temporary teeth are seldom crowded, often standing far apart, which makes room for the later and larger teeth. The temporary molar is usually larger than the bicuspid replacing it. This adjustment enables the permanent teeth to occupy approximately the same space as their predecessors. We have not gone into this problem in detail, because it would take us too far away from the point of view. On general principles, it is obvious that the permanent teeth might, by crowding, slant outward so as to increase the outer anterior dimensions; but this would contribute little to the variability in position of the bases of the teeth. Our object has been to establish an age-limit to growth, so that we could group individuals for comparison. We have shown that, so far as the anterior dimensions of the alveolar arch are concerned, they may be considered fixed at the age of from eight to ten years. The growth in the height of the palate seems to continue to an advanced age. If it can be assumed that the eruption of the wisdom-teeth depends upon the growth of the posterior alveolar process, this growth may continue beyond the twenty-fifth year of life. The height of the palate seems to be correlated with this growth. In the series for the feeble-minded, we have evidence of an increase up to the age of twenty-one and the suggestion of its continuation beyond the twenty-fifth year. The unfortunate thing is, that neither in the normal nor in the feeble-minded series have we a sufficient number of cases to reach a conclusion upon this point.

A hasty inspection of the casts leads to the view that the greater irregularities of the teeth may be found among the feeble-minded. It has been asserted by practitioners, that crowding of the teeth was common because of arrested development of the jaw. Now, crowding of the teeth should push them out of line, and the directions in which they are displaced will be governed by accident: hence all such disturbances will conform to the law of chance. Thus the averages will remain constant, and a comparison upon that basis alone would show no differences. The canines appear to be the greatest sufferers: sometimes they are on the outside, sometimes on the inside, and frequently they are set crosswise between their fellows; yet the averages seem to indicate that they are as often found one way as the other. While we could grade all the casts according to the degree of the crowding

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[1] Quain's Anatomy, 1896, Vol. III, Part IV, p. 52.

of the teeth, and thus answer our problem directly, it is unnecessary, for we have the data for its solution in the previous calculations.

In the first place let us compare the degrees of variability as measured by the value of σ. For normal and feeble-minded children we have the following: —

	Normal–Minded Children.		Feeble–Minded Children.	
	σ for Males.	σ for Females.	σ for Males.	σ for Females.
	mm.	mm.	mm.	mm.
Molar width . .	2.28	2.35	3.01	2.63
Canine width . .	2.31	2.22	3.01	2.36
Length	3.05	2.34	3.09	2.65
Height	1.75	1.96	2.28	2.05

Thus, without exception, the variability is greater for feeble-minded children. For normal and feeble-minded adults the variabilities are as follows: —

	Normal–Minded Adults.		Feeble–Minded Adults.	
	σ for Males.	σ for Females.	σ for Males.	σ for Females.
	mm.	mm.	mm.	mm.
Molar width . .	3.35	3.36	3.61	3.08
Canine width . .	2.24	1.65	2.61	2.89
Length	2.39	2.55	4.27	3.05
Height	2.31	–	2.63	2.66

Again, the feeble-minded are more variable, there being but one case in which the σ for the normal-minded is the greater. The fact that there is such uniformity emphasizes the certainty of the result, even though the differences are small.

The range of values for σ may be estimated by

$$\frac{\sigma}{\sqrt{2n}}$$

Thus for the width at the canines, the difference between the values of σ for normal and for feeble-minded males is expressed as 0.37 ± 0.22 mm. This is by no means a certain difference; and the other differences are of about the same magnitude, except in case of length, where they become positive. As just stated, it is the uniformity of the differences, rather than their magnitude, that indicates a real difference.

Taking the tables as a whole, there seems to be a tendency toward increased variability with age. This is quite pronounced in the width at the first molar and in the height.

Though we have shown that the degree of variation is probably greater in feeble-minded than in normal individuals, it is by no means easy to demonstrate that such is due entirely to the crowding of the teeth, for it will be observed that the height of the palate varies in the same way. Hence, as the case stands, we should expect larger and smaller palates among the feeble-minded than among normal individuals. This, however, is based upon theoretical considerations as to the character of the series, assuming it to be approximately symmetrical.

Character of the Distributions. — In all work of this kind it is desirable that the character of the distribution of cases be inspected. On theoretical grounds it is assumed that the measurements will be equally distributed around the average value. All calculations are made on such an approximate distribution. For purposes of comparison, it is desirable to reduce all distributions of cases to a common denominator of a thousand, or greater. We have given the actual distributions in Tables VI–IX, from which such a reduction can be made by a simple calculation. However, an inspection of the distributions as given will give a general idea of the degree of asymmetry in each case. Thus the widths at the canines (Table IX) are obviously symmetrical in their distribution; the heights and lengths of the palates (Tables VII and VIII) are apparently the same, but in a less degree; while the widths at the molars (Table VI) present some irregularities. Now the best way to test the symmetrical tendency is by calculating the theoretical frequencies for the actual points in the series. The results for such a calculation are given in Table XIV. For normal-minded children it will be observed that the two series agree closely, and that the actual series cannot be said to vary from the theoretical more in one direction than in another. If this variation is due to accident, we should expect the differences to equalize each other, and approximate zero. We have calculated these in the table, and find small residuals. Thus it is evident that we are justified in assuming the variability in this group to be of a symmetrical type conforming to the exponential law, and all conclusions based upon that law will be valid.

Now we must turn to the series for feeble-minded children. As previously shown, the age-differences for this group are too small to be considered significant, so that all male children may be combined. It is apparent from Table VI that all the distributions are of the same type. Thus we have a total of 558 cases with an average width at the molars of 34.04 mm. and a standard variation of 3.4 mm. (Table V). Proceeding as before, we have the results given in Table XIV.

TABLE XIV. DISTRIBUTION OF CASES FOR MOLAR WIDTH.

	Normal-Minded Children.				Feeble-Minded Children.			
Width in mm.	Actual Distribution.	Cases per 1000.	Theoretical Distribution.	Differences.	Actual Distribution.	Cases per 1000.	Theoretical Distribution.	Differences.
22	0	0	0	0	2	3	0	+ 3
23	0	0	0	0	1	1	1	0
24	1	2	0	+ 2	1	2	2	0
25	2	5	1	+ 4	3	5	4	+ 1
26	2	5	2	+ 3	6	11	8	+ 3
27	4	10	8	+ 2	7	12	15	− 3
28	9	20	20	0	12	21	25	− 4
29	19	42	45	− 3	18	32	40	− 8
30	32	72	82	−10	34	61	59	+ 2
31	47	106	126	−20	33	59	79	−20
32	78	175	156	+19	51	92	97	− 5
33	81	182	162	+20	57	103	110	− 7
34	66	149	152	− 3	66	119	120	0
35	45	101	114	−13	73	131	110	+21
36	33	74	71	+ 3	74	133	97	+36
37	14	32	37	− 5	46	83	79	+ 4
38	3	7	16	− 9	34	61	59	+ 2
39	6	13	6	+ 7	18	32	40	− 8
40	0	0	2	− 2	11	20	25	− 5
41	0	0	0	0	1	2	15	−13
42	0	0	0	0	5	9	8	+ 1
43	2	5	0	+ 5	3	5	4	+ 1
44	0	0	0	0	0	0	2	− 2
45	0	0	0	0	1	2	1	+ 1
46	0	0	0	0	1	1	0	+ 1
	444	1000	1000	0	558	1000	1000	+ 1

We have not introduced the series for normal adult males, because the number of cases is much smaller and the average and value of σ are almost the same as for the feeble-minded series.

We may now compare the actual series for the feeble-minded and normal males. Both series of measurements agree in that they reach their greatest frequencies at the same absolute point. In the group of normal males this is probably accidental, since there is a drop at 34 mm. and an acceleration at 36 mm. This is doubtless a disturbance chiefly due to errors in taking the measurements. Whenever fractions of a unit are read to the nearest whole unit, there is a tendency to favor every fifth unit. This would make the frequency for 34 mm. too low, and that for 35 mm. too high. The same disturbance is apparent at 30 mm. and 40 mm. Yet this in itself will not account for all the differences observed, since the value of 36 mm. would tend to be too low. However, when we calculate the differences, as in the preceding case, we have a very small residual for the feeble-minded series. Further, the series for feeble-minded females does not show the same tendency. Hence we way assume again that the distribution is of the symmetrical type.

TABLE XV. DISTRIBUTION OF CASES FOR HEIGHT OF PALATE.

	Normal-Minded Adult Males.			Feeble-Minded Adult Males.		
mm.	Cases per 1000.	Theoretical Distribution.	Differences.	Cases per 1000.	Theoretical Distribution.	Differences.
7	0	0	0	8	1	+ 7
8	0	1	− 1	8	2	+ 6
9	0	2	− 2	0	5	− 5
10	9	6	+ 3	0	12	−12
1	9	16	− 7	26	25	+ 1
2	36	39	− 3	71	48	+23
3	98	75	+23	44	79	−35
4	116	120	− 4	72	113	−41
5	143	158	−15	163	140	+23
6	161	166	− 5	154	151	+ 3
7	170	158	+12	163	140	+23
8	107	120	−13	125	113	+12
9	89	75	+14	80	79	+ 1
20	44	39	+ 5	26	48	−22
1	9	16	− 7	44	25	+19
2	0	6	− 6	8	12	− 4
3	0	2	− 2	0	5	− 5
4	9	1	+ 8	8	2	+ 6
	1000	1000	0	1000	1000	+ 2

The general statement of the case seems to be that the distribution of cases in all the groups for the widths at the first molars approximates the symmetrical type, and conforms to the exponential law. Since we have based all our comparisons upon the applications of this law, we need offer no further justification.

The distribution for the height of the palate cannot be treated so satisfactorily, because of the differences due to growth, which make the combination of children and adults doubtful. We have calculated the distribution for adult males as indicated in Table XV. These calculations show clearly that the two groups approximate the symmetrical type. The calculated differences show small residuals. We have not considered it necessary to apply this test to all the age-groups, but conclude at once that we have again an approximation of the exponential law.

We may now return to the discussion of differences in variability. As we have found a close approximation of the exponential law in all measurements, we can assert that variation is not appreciably greater in one direction than in the other; that is to say, the difference in the value of σ, or the standard variation, is not due to a greater number of cases on one side of the average. The greater variability in width at the first molar, of the feeble-minded for example (if a real difference), would imply that wide as well as narrow palates should be found among the feeble-minded; but an examination of the preceding series will show that large differences of this kind are extremely improbable. An examination of the extreme values in Tables VI–IX will give a general idea of what may be expected in the long-run. Yet it must be noted that such a method of comparison will not adequately reveal small tendencies to increased variability, because of the uncertainty of the frequencies of extreme cases. The tendency in the irregularity of distribution may be concealed in such a way that an objective comparison of the series will be misleading. In the discussion of dentition it was shown that certain disturbances could be accounted for by the eruption of the teeth, and later it was noted that differences in variability between the normal and feeble-minded might be due to disorders of dentition. We are now in a position to make this more probable. Greater irregularity in the position of the teeth will introduce a second variable into our measurements, and this will tend to increase the magnitude of the deviation from the symmetrical type of the distribution of cases. For the width at the canines we have for normal males

$$\sigma = 2.2 \text{ mm.}$$

for feeble-minded males

$$\sigma = 2.6 \text{ mm.}$$

Upon this assumption we have

$$2.6 = \sqrt{(2.2)^2 + x^2}$$

in which x represents the difference in the variability of the position of the canine teeth. By calculation we find

$$x = 1.4$$

In the same way, for the widths at the first molars

$$x = 1.4$$

for the heights of the palate

$$x = 1.2$$

For the females we get similar results. The peculiar fact is, that the values of x tend to be constant. This indicates a constant disturbance affecting all the dimensions. The cause can only be conjectured at this time, but may be the observed effect of malformation of the teeth, tissues, and alveolar process.

From the standpoint of the method we have a result of interest. We have shown by statistical methods the presence of a cause acting upon the morphology of the feeble-minded in an appreciable excess. At the same time the normal type is conserved to such a degree that no other essential difference can be established.

Comparison by Correlation. — So far we have considered the form and size of the palate with reference to isolated measurements. It is obvious that two palates may agree with respect to one dimension, but differ in all others. In Fig. 6 let A_1 A_2 represent a definite width at the canines. Then two palates in which A_1 and A_2 coincide may differ greatly in the position of C_1 and C_2 The same is true for all other points. Thus it appears that the number of ways in which palates may differ as a whole is many times greater than the ways in which they may differ with respect to one dimension. On the other hand, it is probable that variations in one dimension limit those in another dimension; for example, the stature of an individual tends to limit the length of his arm, his weight, etc. In the case of the palate, it seems probable that a great width at one point will necessitate a great width at others: in fact, if the type is as indicated in the foregoing section, this must be the case. Under such conditions it may be that the palate-forms of the feeble-minded differ from those of normal persons in the relative dependence of one dimension upon another; i.e., there may be greater possibilities of combination in one case, leading to greater variety of form.

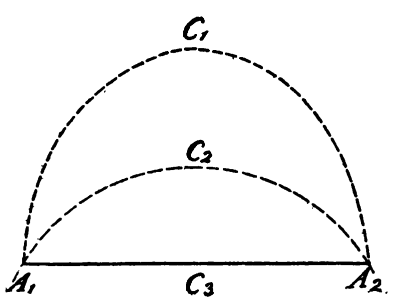


Fig. 6. Diagram demonstrating Relative Dimensions.

The investigation of such relation or correlation has become an important problem in the treatment of biological variation. Methods of treating statistics to bring out such relations have been devised and put in practice so that our way is plain. Let us proceed with a definite part of our task. We have tabulated the normal female children with respect to the measurements at the canines and the first molars in such manner that the place of each case can be seen in each dimension (Table XVI). There are sixteen cases of a molar width of 30 mm., and the array of these under canine measurements give us at once their relation in that dimension. It will be seen that each column, or array, is a variable series, but that its range is less than that of the total series. The Pearson formula for estimating the amount of such limitation in range is the usual method of treating such data. We cannot take the space to demonstrate the method. The formula expresses the degree of correlation in a scale of zero to unity, or from no relation whatever to a perfect correspondence. Yet it should be noted that the interpretation of the whole method of correlation is in terms of the restriction of variation due to an equality in another relation.

TABLE XVI. CORRELATION TABLE FOR NORMAL-MINDED FEMALES, 6–13 YEARS.

Width of Molars in mm.	Width of Canines in Millimetres.															Totals.
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
24	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	1
25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0
26	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	1
27	–	–	1	–	–	–	–	1	–	–	–	–	–	–	–	2
28	–	1	–	–	2	1	–	–	–	–	–	–	–	–	–	4
29	–	–	–	4	2	4	–	1	5	–	–	–	–	–	–	16
30	–	1	–	2	3	1	3	2	3	1	–	–	–	–	–	16
31	1	–	1	1	5	5	5	5	3	–	1	–	–	–	–	27
32	–	–	–	3	7	6	6	16	3	3	3	2	–	–	–	49
33	–	–	–	–	2	5	8	9	5	4	4	2	2	–	–	41
34	–	–	–	–	3	1	6	8	8	6	1	1	–	–	–	34
35	–	–	–	–	–	1	2	10	7	3	–	2	3	–	–	28
36	–	–	–	–	–	2	1	3	1	7	2	3	2	1	–	22
37	–	–	–	–	–	–	–	–	2	1	4	–	–	1	–	8
38	–	–	–	–	–	–	1	–	1	–	–	–	–	–	–	2
39	–	–	–	–	–	–	–	–	1	–	–	1	–	–	1	3
Totals	1	2	2	10	24	27	33	55	39	25	15	11	7	2	1	254

Let r be the degree or coefficient of correlation. Then

$$r = \frac{[xy]}{\sigma_1 \sigma_2}$$

In the table, x represents the deviation of a case in canine width from its average, and y the same deviation of its molar width; σ_1, the standard variation for the canines; σ_2, the same for the molars. Calculating, we find

$$r = 0.67$$

It is also true theoretically that

$$v_2 = \sigma_2 \sqrt{1-r^2}$$

in which v_2 represents the variability of the vertical arrays in Table XVI, or the standard variation in the molar widths of each array.

$$v_2 = 2.38 \sqrt{1-(0.67)^2}$$
$$v_2 = 1.76$$

This means that, if we select individuals with the same widths at the canines, the widths at their molars will be reduced in variability from 2.38 mm. to 1.76 mm. For comparative purposes we may use the value of r as calculated above.

We have calculated the correlations in Table XVII.

TABLE XVII. COEFFICIENTS OF CORRELATION.

	Males.				
Condition.	Normal-minded.		Feeble-minded.		
Age.	6–13	Adult.	6–13	14–20	21+
Canine and molar width . .	+0.44	+0.52	+0.31	+0.30	+0.38
Canine width and height . .	+0.06	−0.27	−0.02	−0.06	−0.11
Molar width and height . .	+0.00	−0.13	+0.09	+0.16	−0.17
Canine width and length . .	+0.11	+0.05	+0.28	+0.19	+0.07
Molar width and length . .	+0.13	+0.03	+0.20	+0.08	+0.03
Height and length	+0.06	−0.02	+0.09	+0.02	+0.11

	Females.				
Condition.	Normal-minded.		Feeble-minded.		
Age.	6–13	Adult.	6–13	14–40	21+
Canine and molar width . .	+0.67	+0.35	+0.42	+0.74	+0.48
Canine width and height . .	+0.15	–	−0.05	−0.15	−0.03
Molar width and height . .	+0.25	–	+0.30	−0.07	−0.06
Canine width and length . .	+0.42	+0.18	+0.23	+0.24	+0.20
Molar width and length . .	+0.33	−0.13	+0.08	+0.08	+0.18
Height and length	+0.30	–	+0.19	+0.15	+0.16

The coefficients of correlation given here are somewhat irregular. The relation between the canine and molar widths, for example, ranges from 0.74 to 0.35. Yet certain tendencies appear. The correlations for females all show a tendency to decrease with age, but this relation is not so clear with the males. Some such difference is to be expected, as it has been shown elsewhere, that, during the growing period, correlations are higher than at any other time.[1] On the other hand we must show what must be allowed for accidental modifications of the degree of correlation.

For females, our series is not quite complete. While marked by one large difference, there is nothing in the general range of values to indicate that this variation is significant of a real difference.

For adults we find the following differences in correlation between normal and feeble-minded males: —

+ 0.14	− 0.02
− 0.16	− 0.00
+ 0.04	− 0.13

The probability of these differences can be estimated by the formula

$$p = \frac{1-r^2}{\sqrt{n}\,(1 + r^2)}$$

For the first difference, 0.14, we have the following: —

$$\begin{aligned} & 0.52 \pm p = 0.52 \pm 0.05 \\ & 0.38 \pm p = 0.38 \pm 0.06 \\ \because\quad & 0.14 \pm \sqrt{(.05)^2 + (.06)^2} = 0.14 \pm 0.08 \end{aligned}$$

from which it follows that this cannot be assumed as a certain difference.

For the second difference above: —

$$\begin{aligned} & -0.27 \pm p = -0.27 \pm 0.08 \\ & -0.11 \pm p = -0.11 \pm 0.09 \\ \because\quad & -0.16 \pm \sqrt{(0.08)^2 + (0.09)^2} = -0.16 \pm 0.12 \end{aligned}$$

Again the difference is within the limits of the accidental, and, since these are the maximum differences, it appears that the differences in the degrees of correlation between the two groups are insignificant.

So far we have treated the widths of the palate without considering the lengths. On general principles it may be assumed that a wide palate will be long; i.e., large in totality. The table of correlations shows that this is not true, except to a very slight degree. For adults there is practically no relation between length and either of the two widths. The coefficients are,

[1] Statistics of Growth (Report of Commissioner of Education, 1904, pp. 25–49).

however, positive, which implies a tendency to a slight relation; but the degree is so small that it counts for nothing in our present data. There is a suggestion that this relation is closer in childhood than in later life.

It may not be legitimate to correlate width at the canines with length forward from the molars: hence we have calculated the coefficients for the length as measured from the canines forward.

NORMAL MALE ADULTS.

Width at canines and length forward	+0.08
Width at canines and length from canine to first molar	+0.04
The two parts of the length in the above	+0.04

From this it appears that the length is not related to the width, and that one part of the length is not related to the other. We have not deemed it worth our while to carry the calculations further, since they seem decisive. The general result seems to be, that whether palates are long or short is of no consequence with respect to their width.

The height of the palate must be considered next. The cavity of the roof of the mouth may be regarded as a solid, of which the height is one of the dimensions. The widths and the lengths are dimensions of its base. The correlation table indicates a tendency for adults toward negative coefficients. The degree of such correlation is small, but implies that a narrow base is often found with an increased height. When we consider the irregular character of this solid and the inadequate way in which the height represents its altitude, it may be assumed that the tendency in this direction is much greater than appears in the calculation. We made several attempts to estimate the area of the palate. We took the product of the length and width at the first molar as an approximation of the area, and obtained a correlation of +0.02. Then we took half of the sum of the canine and molar widths, and multiplied it by the length: the correlation was − 0.18. Since the space forward of the canines is taken up mostly by the alveolar processes, the cavity may be more truly represented by the width at the canine (a), the width at the molar (d), and the perpendicular distance between them (c). Then

$$\frac{a+d}{2} = \text{the average width}$$

$$\frac{(a+d)}{2}c = \text{the area}$$

If we take the square root of this, we shall have the side of an equivalent square, which reduces our series to smaller units.

$$\text{Av.}\left[\sqrt{\frac{(a+d)}{2}c}\right] = 25.1 \pm 1.7 \text{ mm.}$$

Correlating this value with height gives -0.15. Thus the general result has not been modified by these calculations. The interpretation of these results is, that the relation between the height of the palate and the other dimensions is one of compensation; i.e., that when the jaws are narrow the roof is high. It may be objected that the capacity of the palate cavity should have been measured. The attempt was made in various ways. The average capacity from the first molar forward for normal males was

$$6.9 \pm 0.8 \text{ grms.}$$

and this, correlated with the height ± 0.15.

This result is not necessarily contradictory to our previous conclusion, because the height is now a factor of the capacity, and the same relation holds as with the canine and molar widths discussed above. A great capacity will necessitate a like tendency in height, but there may be compensatory relations between the height and the other dimensions involved. Yet the reader should keep strictly in mind that we are dealing with very small differences, and that the tendencies of relation here may prove accidental.

By way of interest we have calculated the correlation for capacity and the following: —

Molar width	112	+0.47
Canine width	113	+0.15
Length	111	+0.33

It seems that the width at the first molar is the best index of the size of the cavity of the palate. This is one of the reasons that led to the selection of this measurement for our comparative study.

We also measured the length of the curve of the teeth with a wheel, and found an average, for seventy-one cases, of 76.4 ± 5.6 mm. The correlations for this were —

Height	+0.05
Canine width	+0.49

In general we found the height rather independent of dimensions in the horizontal plane. Where tendencies appear, they are in the direction of a compensation; i.e., the cavity of the palate tends to reach a certain size, and resistance in one direction leads to expansion in another.

When the coefficients of correlation for children and adults are compared, we find a few large differences. For normal female canine and molar width the difference is considerable; but the cases are so few for adults that it cannot be regarded seriously. The other large difference is found in the correlation between the molar width and the height of the palate for feeble-minded females, a difference of 0.36 ± 0.12. This alone will not bear much weight, as such differences are to be expected occasionally. The same is true of the large differences for the group 14–20 and adults.

The general comparative statement is, that we have failed to establish a relative difference between the measures of the palates of normal and feeble-minded individuals.

In a preceding section we considered the relative importance of the various possible measurements, and we now find ourselves in a position to consider it further. We have measured a series of normal palates in a great many ways, and these data may be correlated so as to bring out differences of relation. We shall take the horizontal plane first. The inside width of the outer incisors as correlated with the other widths is as follows: —

	n	*r*
Outer incisors and canines	105	+0.69
Outer incisors and first bicuspid	87	+0.71
Outer incisors and second bicuspid	90	+0.67
Outer incisors and first molar	105	+0.52
Outer incisors and second molar	87	+0.38

The canine width: —

First bicuspid	91	+0.73
Second bicuspid	–	–
First molar	125	+0.52
Second molar	90	+0.31
Second bicuspid and second molar	83	+0.60

As these coefficients stand, they imply that the nearer the points at which widths are taken, the greater the agreement between them. This is another way of stating a previous assumption, that the form of the palate is such that an almost endless variety of forms can result from a combination of the points enclosed by the limits as defined in Fig. 3. A palate very narrow at the canines would not place a great limit upon the width at the second molar; for by the formula

$$v = 3.0\sqrt{1 - (0.31)^2}$$
$$v = 2.8$$

So we may find opposite exttrmes in width at these points, giving us an extreme V-shaped palate; but this would not constitute a type. A very common error is to take the normal variant in a type as a new type.

At this point we must enter into a consideration of the method of correlation as applied to data of this kind. Assuming the palate to be a distinct organ, it will be observed that the width at the canine, as measured, is contained in the width at the first molar. In correlating we take the product of x and y, the respective deviations of A and C from their averages (Fig. 7). Hence we see that x is contained in y, since A is contained in C. Hence A and C will be correlated by virtue of what they have in common. If there were no variations in the relative values of C–A, the correlation between A and C would be perfect, or a coefficient of 1.00. Since we obtained a different result, we must examine the case critically.

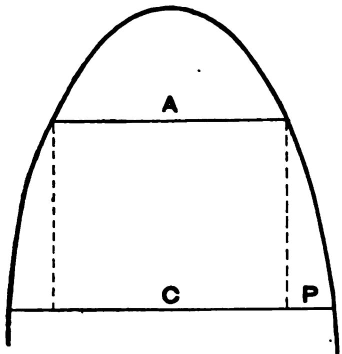


Fig. 7. Diagram demonstrating the Correlation of Identical Parts.

We may assume that OM represents any type-curve (Fig. 8). Let A and C be ordinates of the same. Indicate average by brackets.

Then let

$$[C] - [A] = [P]$$

and σ_a, σ_c, σ_p = the respective variabilities of these averages.

$$x = \text{the deviations of A from [A]}$$
$$y = \text{the deviations of C from [C]}$$
$$y = x + p.$$

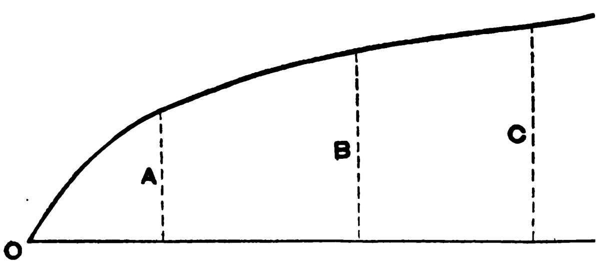


Fig. 8. Type-Curve.

Then $(x + p)$ is a variable agreeing with a variable y; p is the deviation of [P].

$$[xy] = [x^2] + [xp]$$
$$[y^2] = [x^2] + 2\,[xp] + [p^2]$$

Also

$$[y^2] = \sigma_c^2$$
$$\sigma_c^2 = \sigma_a^2 + \sigma_p^2$$
$$[y^2] = [x^2] + [p^2]$$

Hence $[xp]$ should be zero; but this can occur only when there is no correlation between A and P.

The value of p may be expressed as

$$[p^2] = [y^2] - 2\,[xy] + [x^2].$$

Now the various terms of these equations can be calculated from the data for the correlation of A and C.

$[xp]$ corresponds to the $[xy]$ in the correlation formula, or is the value from which r_{xp} can be calculated when σ_p is known. Taking A and C as the widths at the canines and molars respectively for normal adult males, we find the following: —

$$r = +\,0.52$$
$$[xy] = +\,4.21$$
$$\sigma_a = 2.50$$
$$\sigma_c = 3.35$$

Substituting in the preceding equation, we find

$$\sigma_p = 3.00$$

and

$$[xp] = -\,2.04$$

Then

$$r_{xp} = -\,0.27$$

Thus, while the direct correlation between the two widths is + 0.52, the correlation between the smaller and their differences is − 0.27. This implies that, if a palate is wide at the canines, the spread of the jaw at the first molar will tend to be less than the average, and the reverse.

This result is such, that we must give these correlations detailed consideration. In the first place we have calculated for direct comparison the actual values as obtained by measurement, and find: —

$$[xp] = -\,2.06$$
$$\sigma_p = 2.80$$
$$r_{xp} = -\,0.29$$

The agreement is close. While the correspondence may not be so close in every case, there is no reason why the actual values should not approximate the values of the formula.

From our correlation tables we have calculated these values for the outer incisors as follows: —

	$[xy]$	$[xp]$	σ_p	r_{xp}	r_{xy}
Incisors and canines	+3.04	− 1.37	±2.14	− 0.30	+0.69
Incisors and first bicuspid . . .	+6.08	+ 1.67	±2.88	+ 0.28	+0.71
Incisors and second bicuspid . .	+5.03	+ 0.62	±2.25	+ 0.13	+0.67
Incisors and first molar	+3.91	− 0.50	±2.79	− 0.09	+0.52
Incisors and second molar . . .	+2.70	− 1.71	±2.95	− 0.27	+0.38

For the canines as the point of departure: —

Canines and first bicuspid	+6.78	+1.94	±2.96	+0.26	+0.73
Canines and second bicuspid	–	–	–	–	–
Canines and first molar	+4.21	−2.04	±3.00	−0.27	+0.52
Canines and second molar	+2.37	−2.47	±3.20	−0.30	+0.31
Second bicuspid and second molar	+5.94	−4.81	±2.93	−0.50	+0.60

We find in general that the correlations are very much reduced, and tending toward a change of sign, when the common element has been eliminated. With this element included, the correlations decrease inversely with the distance between the correlated dimensions. By the calculations we have shown that, when the element in common is removed, there is a tendency to reverse correlation.[1]

We may now consider our problem as that of a curve tending to approximate a certain form (Fig. 8). Let *O* be the point of origin, and *A*, *B*, *C*, any of the successive ordinates. Accidental causes operate to change the direction of the curve, and thus vary *A*; but, as the tendency of the organ is to reach a definite type as to magnitude as well as to form, the curve will approach *B* and *C*. Thus extreme variation in the length of any ordinate will be accompanied by less variation in the others. Thus our correlation as calculated should be negative in tendencies, because a high value in one is associated with a lower value in the other. On the other hand, the nearer the ordinates correlated, the higher the degree of direct or positive correlation, because, if *A* is correlated with itself, the coefficient will be 1.00. We have shown that, in the method of estimating correlation, allowance must be made for this common factor in the product of the moments. By a corresponding reduction we may find a point upon the curve where there is no correlation. This point has a geometrical relation to positive and negative correlation, and a functional relation analogous to the no-correlation point for growth-measurements as determined by Boas.[2] The general point is, that the organ tends to fill a definite space in a definite way, and that excess in one portion is met by adjustment in the other.

In the foregoing we have noted that the measurements at the canines were not correlated with those of the incisors, as with the other teeth, which is probably another phase of the peculiar position of these teeth and the phenomena of crowding as an abnormality of dentition. The variabilities

[1] For an analogous result see Professor Franz Boas, the Cephalic Index (American Anthropologist, N.S., Vol. I, 1899); see also Dr. Clark Wissler, the Spearman Correlation Formula. (Science, Sept. 8, 1905).

[2] Statistics of Growth (Report of Commissioner of Education, 1904, p. 31).

for P as expressed by p are greater for the canines than for the incisors and the second bicuspids.

We have the data for different measurements at the canines and the first molars.

Correlation of inside widths at the canines and molars	+ 0.52
Correlation of outside widths at the canines and molars	+ 0.53
Correlation of the above widths measured from the median lines of the teeth	+ 0.54
Correlation between the width at the median line of the molar and inside width	+ 0.87

Hence, as before stated, it makes little difference what points on the teeth you select for measuring, since they all give approximately the same relative values.

Before closing the discussion it may not be out of place to try multiple correlation. Designating length of palate by C, width at first molar by A, at the canines by D, and the height by B, we may calculate from our previous data correlations after the following: —

$$r_{AC(B)} = \frac{r_{AC} - r_{BC} r_{BA}}{1 - r^2_{BC}}$$

$$r_{AB(C)} = \frac{r_{AB} - \dots}{1 - \dots}, \text{ etc.}$$

We find

$$r_{AC(B)} = + 0.03$$
$$r_{AB(C)} = - 0.13$$
$$r_{BD(A)} = - 0.28$$
$$r_{AB(D)} = + 0.01$$
$$r_{AD(B)} = + 0.68$$

With two exceptions, the coefficients approximate zero. The height of the palate as affected by the related widths shows a marked correlation, while the height and canine width against the molar width give a negative coefficient. However, the preceding discussion has revealed the disturbing factors in such correlations.

The general import of this examination of the correlation of dimensions seems to be that there cannot be a strict type-difference between the interior dimensions of the palates of the feeble-minded and those of normal individuals. If such differences held, there should be emphatic differences in the degrees of correlation for the two groups. As it stands, extreme abnormalities of the palate are about as frequent among individuals of one group as among those of the other.

Head-Measurements and the Palate. — The physical measurements of feeble-minded individuals afford opportunities for correlating the palate and other organs. For adult males, the following correlations were calculated: —

	n	*mm.*
Width at molars and width of face	111	+ 0.36
Height of palate and width of face	100	+ 0.14
Width of molars and stature	114	+ 0.09

The only case that seems to promise a relation is that of the molar width and the width of face; yet it will be observed that the others tend to positive correlation, or toward general size-relation.

Summary. — This comparison has shown that, so far as our data go, the general type of the palate as defined by the measurements taken is the same for feeble-minded as for normal individuals.

We have shown that the general type of palate as defined by the average measurements is the same for feeble-minded as for normal individuals. The method of correlation was found to give no reliable result as to differences in relative size. The only case in which a probable difference appears is in the degree of variability; but, as we have shown, the excess in favor of the feeble-minded is not a matter of great certainty. Granting that this should be true, it may be maintained that there is a palate peculiar to the feeble-minded, since their palates will sometimes be longer and again smaller than those of the normal-minded; but this would be an error, because we have failed to find a degree of correlation between the measurements that would lead us to expect palates to show corresponding differences at all points. A greater variability for the measurements as taken would mean greater irregularity of points corresponding to the teeth.

This would be accidental variation from the normal type, that is, in no one direction. The many minor results of the foregoing studies need not be repeated here.

COMPARISON BY QUALITATIVE GRADATIONS.

In another part of this paper we have pointed out that the tendency was for the palate-form to approximate the type, and that an extreme variation at one point would be compensated at another. Then, if the variability is truly greater for the feeble-minded, we should expect greater irregularity for them, though the averages and the type should be the same as for the normal-minded. The correlation between the respective dimensions will not necessarily differ in either case, since the degree of correlation is in a measure due to geometrical relations common to both classes, as we have shown. Thus the correlation method will not solve our problem directly. We proceeded upon the assumption that it would. On the other hand, it seems reasonable to assume that the observed difference in variability between the two classes indicates a condition of greater irregularity in contour. As we have seen, direct measurements fail to reveal any other evidence of difference.

We must now consider the method of grading by eye. Previous research in relation to this problem contented itself with a general estimate of the form and degree of the irregularities of the palate, but usually the form received the chief consideration. At one time Dr. Channing classified by inspection our material under five heads, as follows: —

1. V-shaped.
2. Partial V-shaped.
3. Semi V-shaped.
4. Saddle-shaped.
5. Normal or U-shaped.

The result was as follows: —

TABLE I.

Classifications of Palates of 1000 Idiots.

V-shaped	19.0	48.1
Partial V-shaped	24.8	
Semi V-shaped	4.3	
Saddle-shaped	11.0	
Normal or U-shaped	40.9	

"From this table it may be seen that about forty-one per cent of idiots have palates which are of fairly good shape, and cannot be regarded as falling into any classification of pathological palates, if shape is to be the criterion.

"The difficulty of making correct inferences from statistics can be graphically shown by the next two tables I present, which are arranged after the method of Talbot: —

TABLE II.

Showing Varieties of Palates in Presumable Normal Individuals. Collection of Drs. Sheppard and Cooke of Casts taken before Correction of Irregularities of the Teeth.

No.	Normal.	Large Jaw.	High Vault.	V-shaped Arch.	Partial V-shaped Arch.	Saddle-shaped Arch.	Small Teeth.
212	22.1	5	5	16.5	42	19.3	0

TABLE III.

Showing Varieties of Palates in Presumably Normal School Children over Twelve Years of Age. Not from Casts. (Dr. Talbot.)

No.	Normal.	Large Jaw.	High Vault.	V-shaped Arch.	Partial V-shaped Arch.	Saddle-shaped Arch.	Small Teeth.
1000	78	1.9	5.6	1.1	6.1	3.3	3

"In Table II it will be seen there was an enormous percentage of deformities, far in excess of that in Table III, and nearly 30 per cent in excess of that figured in Table I, of idiots' palates. Table II shows 42 per cent partial V-shaped arches, which Table III gives as only 6.1 per cent, and Table I, 24.8 per cent.

"From these statistics it would appear that one class of the general community not only has more deformities than another, but actually more than obtained among idiots. The statistics in Table II were made from casts by myself, at leisure and with care. Those in Table III were not made from casts, and therefore, though no doubt carefully compiled, were more liable to error." [1]

The contradictory result in these tables is characteristic of the method, because of the difference between observers and their standards, and we deem it unwise to give further attention to the mere grading by eye.

However, it is our experience that irregularities of the teeth give one a wrong impression as to the form of the palate. Since we have disposed of form and size by measurement, we may be able to grade the irregularities of contour in the horizontal plane, if the teeth are eliminated. To this end we traced in natural scale the inner curve of the teeth, using a form of pantograph. A few of these tracings are shown in Plates XIX–XXII. These were selected at random, and may be taken as a chance series such as might be secured from an equal number of individuals taken in the same manner. The numerals below the graphs refer to the records of individuals furnishing data for this research.

We have attempted to grade the whole collection of tracings by regularity of outline, regardless of palate-forms. In the preceding pages we have suggested that the observed difference in variability between the palates of feeble-minded and normal individuals was due to greater crowding of the teeth in the feeble-minded. If this were true, the outlines of the teeth as traced with a pantograph should be more irregular for this class. To test this we compared tracings for adult normal males with an equal number

[1] The Significance of Palatal Deformities in Idiots (Journal of Mental Science, January, 1897).

for adult feeble-minded males, pasted upon separate cards. The two lots were thoroughly shuffled. Five were drawn from each lot, and arranged according to rank in regularity. The following is one of the series, in which *n* and *f* represent normal and feeble-minded respectively; the first numeral the highest rank:—

1	2	3	4	5	6	7	8	9	10
f	*n*	*n*	*f*	*f*	*n*	*f*	*n*	*f*	*n*

The resulting series for eighteen such drawings gave the following totals:

Rank	1	2	3	4	5	6	7	8	9	10
Normal-minded . .	11	8	5	7	9	12	10	9	10	6
Feeble-minded . .	7	10	13	11	9	6	8	9	8	12

If there were no differences in irregularity, there should be an equal number of palates in each half of the above table. Taking the middle points, we have:—

Normal-minded	40–47
Feeble-minded	50–43

While there is here the suggestion of a difference in favor of the feeble-minded, it is too small to be considered. Another trial of two tracings of each class gave the following:—

Rank	1	2	3	4
Normal-minded	17	14	10	5
Feeble-minded	6	9	13	18

This table seems to indicate a difference in regularity in favor of the normal. With extended series of fifty of each class, taking two at a time, we found the number of cases taking first rank to be:—

	Normal-minded.	Feeble-minded.
First series	27	23
Second series	31	19
Third series	25	25
Fourth series	26	24
Fifth series	30	20
Sixth series	32	18
Average ratio	14–11	

Again the indication is that the teeth of the feeble-minded are more irregular than those of the normal-minded.

These gradations must be taken as indicating, on the whole, somewhat greater irregularity among the feeble-minded. It is evident, however, that the variation in this respect is not very great, and we fail to see that this result differs in any way from that obtained by measurement, except that it is far less definite and certain. We have shown clearly that the calculated variability was slightly greater for the feeble-minded.

TABLE XVIII. PALATE-MEASUREMENTS FOR ESKIMO SKULLS.

	Width at First Molar.	Height of Palate.	Width at Canines.	Length of Palate.	Height of Palate from Alveolar Process.
	mm.	mm.	mm.	mm.	mm.
	37	13	23	26	6
	38	15	23	28	13
	43	17	24	23	9
	40	19	31	24	7
	36	–	–	26	–
	41	18	25	26	12
	45	22	25	26	17
	41	16	28	27	10
	42	18	26	23	11
	33	15	23	25	11
	43	16	22	26	11
	43	14	23	30	10
	43	26	25	26	21
	35	14	23	23	11
	40	13	21	28	9
	40	13	25	26	6
Average	40.0	16.6	24.5	25.1	11.1

TEST-MEASUREMENTS ON SKELETAL MATERIAL.

Since objections may be made to the use of casts and even to measurements upon the living, it became desirable to measure skulls. We have not had access to the skulls of feeble-minded or normal-minded white persons, but to a respectable series for other races. One of the first points considered was the comparison of measurements for the height of palate. On the casts we measured this from the gum-line; on skulls the measurements may be taken from the alveolar border or from the masticatory plane of the teeth. A series of sixteen Eskimo skulls examined by us still retained the mark of the gum-line, all being from recent burials. Accordingly we measured these skulls by the same method as that used for casts, adding the height as measured from the alveolar border. The results are given in Table XVIII. We also measured the height from a series of Chinook skulls with the following result: —

	n	Alveolar Border.	Masticatory Plane.
Males	26	16.5 ± 1.9	21.4 ± 1.7
Females	40	14.5 ± 2.6	19.4 ± 2.5

This indicates that, in so far as variability is concerned, measurements on skulls are no more constant than those upon casts. Though these are skulls of another race, we can compare the two measurements above with the corresponding two on casts (p. 302). The value of σ is approximately the same, and there is the same quite constant difference of 5 mm. between the two planes. Therefore we are of the opinion that measurements made upon the living, or upon casts from the living, are about as useful as those made upon skulls.

As a matter of general comparative anthropological interest we have made other measurements on skulls, the averages for which are given in Table XIX. We have also a series of modern Mexican Indian skulls with the following: —

	n	Av. mm.	σ mm.
Width at first molar	58	35.4	2.5
Length from first molar	62	27.3	1.9
Height from alveolar border	90	14.7	3.0

Treating the measurements in Table XIX as in the discussion of normal-minded palates of the white race, we could indicate the Chinook type; but this would take us too far afield. It may be noted, however, that all the measurements here given indicate that the palates of aboriginal American races are broader and shorter than those of white Americans. The height of palate, however, seems about the same for all, though there is reason to believe that measurements of height will be of greater magnitude for skulls than for casts from the living.

While engaged in the preceding skull-measurements, Dr. R. H. Lowie made some observations upon the transverse palatine suture, his statement being as follows: —

TABLE XIX. PALATE-MEASUREMENTS FOR SKULLS.

	Chinook Indian.						Kwakiutl Indian.					
Measurements.	Male.			Female.			Male.			Female.		
	n.	Av. mm.	σ mm.	n.	Av. mm.	σ mm.	n.	Av. mm.	σ mm.	n.	Av. mm.	σ mm.
Inside width at												
1st bicuspid .	6	–	–	13	27.4	2.5	–	–	–	–	–	–
2d bicuspid .	3	–	–	11	32.0	2.5	–	–	–	–	–	–
1st molar . .	19	36.3	2.7	34	34.9	2.9	6	35.4	–	14	33.8	2.8
2d molar . .	16	41.2	2.8	27	39.5	2.5	–	–	–	–	–	–
3d molar . .	11	43.4	2.5	9	42.4	3.1	–	–	–	–	–	–
Length from												
1st bicuspid .	16	11.4	1.7	25	11.0	1.4	1	27.0	–	4	24.0	–
2d bicuspid .	15	17.6	2.4	22	17.0	1.9	–	–	–	–	–	–
1st molar . .	23	25.6	2.2	39	25.6	2.2	6	25.8	–	16	25.8	1.9
2d molar . .	19	34.4	3.0	36	33.9	3.1	–	–	–	–	–	–
3d molar . .	19	41.7	3.2	16	41.3	3.1	–	–	–	–	–	–
Maximum height from masticatory												
plane	25	21.4	1.7	40	19.4	2.5	6	23.6	–	16	20.2	2.6
alveolar border	26	16.5	1.9	20	14.5	2.6	10	16.6	2.0	17	14.2	2.1

While Stieda,[1] Killermann,[2] and Bauer [3] have investigated the form of the transverse palatine suture in different peoples, the American skulls at their disposal were hardly numerous enough to warrant any definite conclusions on the character of the suture in the American race. Stieda gives the results for 103 "Rassenschadel" without further specification;[4] Killermann examined only twenty American skulls;[5] and Bauer founds his percentage for different types in the Indian race on five Botocudos and five Fuegians.[6] Accordingly, it seemed worth while, when taking the preceding palatal measurements, to take note of the sutural types in a fair number of cases, and check the figures given by Bauer and Killermann.

Following Stieda's classification, both the later investigators distinguish three fundamentally distinct types, — the straight, the projecting, and the receding suture. Stieda and Bauer recognize in addition a class of irregular forms. By these, Bauer understands transitional forms;[7] and Stieda defines them as combinations of different types on the right and left side, including, however, those cases where the suture is straight on both sides, but on a different level. The principal difference in counting forms is due to the classing by Killermann of sutures that are straight on one side and receding on the other with the receding type, and to his disregard of the super-

[1] Arch. f. Anthrop. 1894, Vol. XX, pp. 1–11.
[2] Arch. f. Anthrop., 1894, Vol. XX, pp. 393–424.
[3] Ach. fr. Anthrop., 1904, N. F. Band II, pp. 178–180.
[4] l. c., p. 9. [5] l. c., p. 398. [6] l. c., p. 179.
[7] l. c., pp. 178, 179.

numerary class of transitional irregular forms (p. 395). The results obtained by the three investigators for skulls in general are as follows: —

	Projecting.	Straight.	Receding.	Irregular.
	per cent.	per cent.	per cent.	per cent.
Stieda	64.54	20.98	9.53	4.92
Bauer	17.4–30.8	30.8–53.4	4.3–10	20–39.1
Killermann	67.65	15.63	16.72	–

Stieda's and Killermann's results are in tolerable agreement, the slight discrepancies being fairly accounted for by the difference in classification. Killermann and Bauer agree in finding the straight type predominant in the American race (55 and 50 per cent): this would simply agree with Bauer's average for all races, but marks the greatest racial deviation recorded by Killermann (p. 398). For the projecting suture they give the percentages 30 and 20 respectively. Though Killermann distinctly deprecates the notion that the form of the suture could be utilized as a racial characteristic (p. 404), the marked difference in the distribution of sutural types found by him in the American race, as distinguished from others, could not be considered wholly insignificant if corroborated by more extended observations. I have therefore examined a considerable number of skulls from several Indian tribes, classifying sutures according to Stieda's and Killermann's divisions as follows: —

	Stieda.							
	Projecting.		Straight.		Irregular.		Receding.	
	n	%	*n*	%	*n*	%	*n*	%
Mexican	68	59.13	12	10.43	29	25.22	6	5.22
Chinook	49	63.63	9	11.68	15	19.48	4	5.19
Kwakiutl	18	66.67	2	7.41	3	11.11	4	14.82
Bolivia	66	60.00	12	10.91	20	18.18	12	10.91
S. E. Utah	15	45.45	2	6.06	9	27.27	7	21.21
Nootka	10	71.43	0	0.00	2	14.18	2	14.28
British Columbia	14	56.00	2	8.00	6	24.00	3	12.00
Eskimo	26	45.17	3	6.25	9	18.75	10	20.83

	Killermann.							
	Projecting.		Straight.		Irregular.		Receding.	
	n	%	*n*	%	*n*	%	*n*	%
Mexican	78	67.83	20	17.39	3	2.61	14	12.17
Chinook	53	68.83	15	.19.48	3	3.89	6	7.79
Kwakiutl	18	66.67	3	11.11	3	11.11	3	11.11
Bolivia	77	70.00	13	11.82	1	0.91	19	17.27
S. E. Utah	19	57.57	2	6.06	5	15.15	7	21.21
Nootka	10	71.43	0	0.00	2	14.28	2	14.28
British Columbia	15	62.50	2	8.33	1	4.17	6	25.00
Eskimo	28	58.33	6	12.50	2	4.17	12	25.00

GENERAL DISCUSSION OF RESULTS.

At the outset we stated our intention of directing the major part of our efforts to the application of anthropometric methods to the comparative study of the hard palate among feeble-minded and normal-minded individuals. As every one must know, there are two time-honored methods of procedure in comparative morphology, — a qualitative visual one and one of quantitative estimation according to some unit of measure. In the preceding pages we have given the latter a fair though not an exhaustive trial, bringing into play most of the known anthropometric and statistical methods. While it is true that these methods are in large measure based upon assumptions, we have kept as close as practicable to empirical methods of treatment. In work of this kind we are confronted with the necessity of distinguishing between differences due to real and to accidental variation, — a task by no means simple, since in observation the two always coalesce. It is chiefly here that theoretical aid must be sought. We have considered all differences as accidental, unless they exceeded the theoretical limits of accidental variation. Now, while some of these rejected differences may be real, it must not be overlooked that such differences will in any case be exceedingly small, and therefore minor factors in the general variability. It seems certain that few positive quantitative differences can escape detection by comparative measurements. Hence the general result of this part of our work must receive due consideration.

Every one should bear in mind that while anthropometric methods detect differences, these methods are in themselves impotent in interpretation. We have in the main contented ourselves with a statement of differences found and not found, though, in case of dentition and growth, we have by analysis given certain interpretations of observed differences. On the other hand, we do not offer an interpretation of the small though seemingly constant difference in variability between the normal and feeble-minded. While there are reasons for considering as phenomena of dentition among the feeble-minded the want of positive difference in the size of the palate as measured, the apparent qualitative difference of greater irregularity in the alignment of the teeth, and the greater variability as shown by the size-measurements (all appearing to be different expressions of the same morphological relation), it is not quite clear how these could be without positive differences in the teeth themselves. The suggestion from the data on dentition, to the effect that the permanent teeth tend to erupt earlier among the feeble-minded, appears as a possible explanation of crowding; yet more data will be needed to establish this apparent difference in the dentition-periods, before such an explanation can be seriously considered. Aside from any such interpretation, the fact remains that our method reveals evidences of a slight difference in the degree, but not in the kind, of variability between the normal and feeble-minded. Our rather detailed determination of the type both as to coincident and correlated points shows that the palates of all form an apparently homogeneous group, or are identical in type as determined by the average. What difference there is shows apparently a slightly greater variability for the feeble-minded. This difference, however, is distributed with approximate equality among the minimum and maximum values, thus failing to substantiate the assumption that the palates of the feeble-minded are relatively narrow. Finally, all the differences we have discovered in size are too small to be detected by the eye, and hence are of no practical clinical value.

While the same general fact might have been discovered by a qualitative gradation of irregularity as previously demonstrated, such a method could not have brought out the many points of importance suggested by the anthropometric method. This gradation method could not, for example, discover the presence of an apparent constant invariability affecting equally all of the palate-measurements in horizontal plane as calculated from our data. We have had neither the time nor the necessary data to compare in this way the variabilities for other organs. This would be an interesting problem in itself. The results suggest that the differences in variability shown for the feeble-minded are due to a general retardation effect during the first few years of life, which is in keeping with an assumption made by Dr. Channing in one of his earlier papers. The results of our study of the growth of the palate suggest, that, since the parts anterior to the molars take form early in life and the greatest change in height occurs during adolescence, the greatest differences may be expected in the latter. A return to the measurements, however, shows that this expectation has not been realized. As to the parts posterior to the first molars, it need only be recalled that the measurements at the second molars show even less difference than elsewhere.

Incidentally we have given the method by correlation a fair test both theoretically and actually. The method certainly has great limitations, for, as we have shown, certain mere geometric relations may enter into the result, giving a greater or less degree of correlation, as the case may be. This objection may not, however, hold for correlations between measurements in different planes, or between measurements of different organs, as legs and arms. On the other hand, it cannot be said that the method failed even in our case, though the result is less satisfactory than it would have been under other conditions. The peculiar range of correlation values from positive to negative seems accounted for by the compensatory nature of growth, by which a marked deviation in one part of an organ is equalized by deviations in other parts. In correlations between distinct organs, this factor would tend to disappear.

In some respects the most important of the new data we offer is that pertaining to growth and dentition, which may be considered independently of the problem at hand. There are good reasons for expecting no growth in the anterior horizontal plane of the palate after the ninth or tenth year, in so far as many of the permanent teeth are by that time in place. The surprise at the result, if such there be, is doubtless due to an error in observation, since the eruption of the second and third molars gives the curve of the teeth a more extended appearance. The subject of growth in general is an important matter to many theoretical sciences, and it is in this field that anthropometric methods seem most fruitful.

In this study we have not considered the condition of the gums and other soft tissues, but have confined our efforts to the search for differences in the conformation of the osseous structures forming the hard palate. Naturally the teeth were taken as points of departure. That casts introduce errors of measurement is probable; but our critics should not be led astray by forgetting that such errors are either constant or accidental. If they are constant, they affect all individuals alike, — a condition of no consequence in a comparative study. If they are accidental, they will not change the average measurement, and, while the variability will thereby be increased, this increase should be constant when casts are used throughout.

In conclusion we wish to express our obligations to Professor Franz Boas for valuable criticism and guidance in many phases of the work at its inception. We are also indebted to Viola Gebhart Wissler for many of the calculations, and to Dr. R. H. Lowie for assistance in anatomical measurements.

TABULATED DATA.

The writers of this paper have prepared and placed on file in the American Museum of Natural History complete tables of all measurements collected by them, copies of which can be supplied to investigators at trifling expense. These tables contain the age, stature, and weight of the subjects furnishing us palate-casts. For the feeble-minded we have added head-measurements. The casts themselves may be examined upon application at the Department of Anthropology.

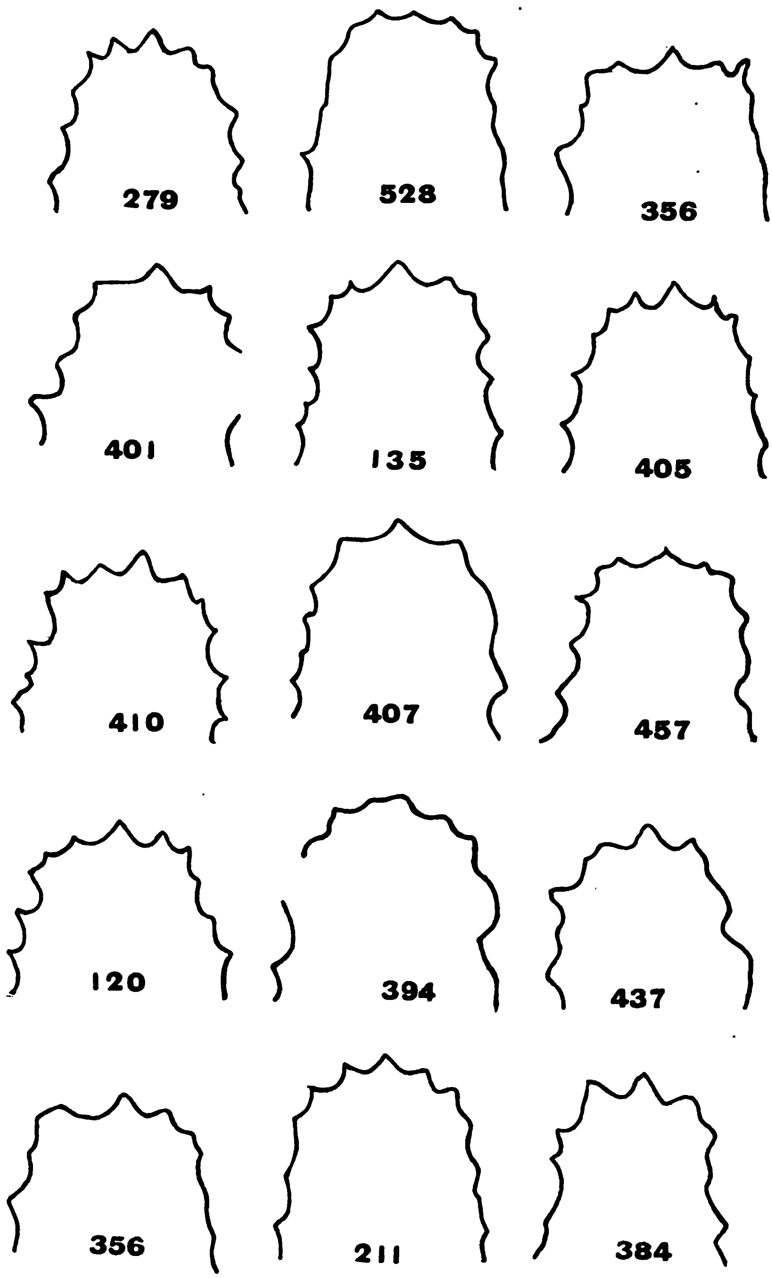
Palates selected according to Molar Width.

Palates selected according to Height.

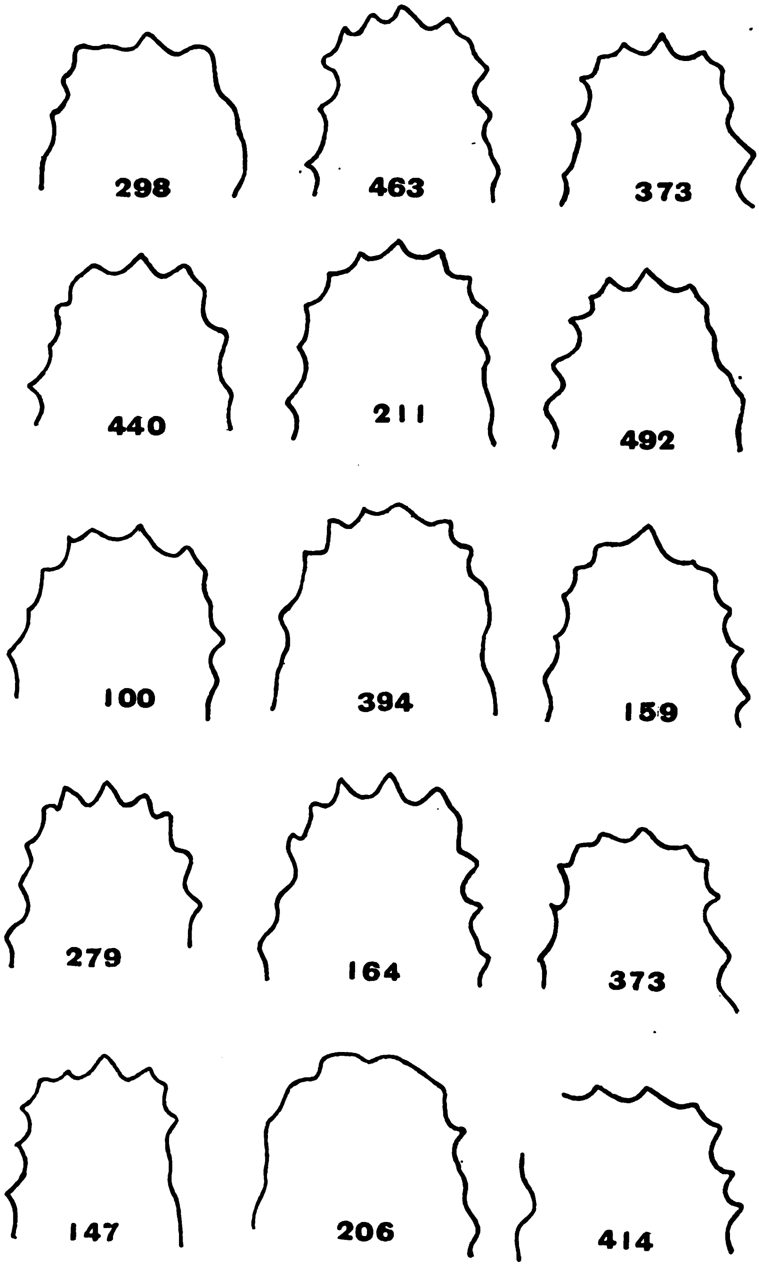
Palates selected according to Length.

PALATES SELECTED ACCORDING TO CANINE WIDTH.

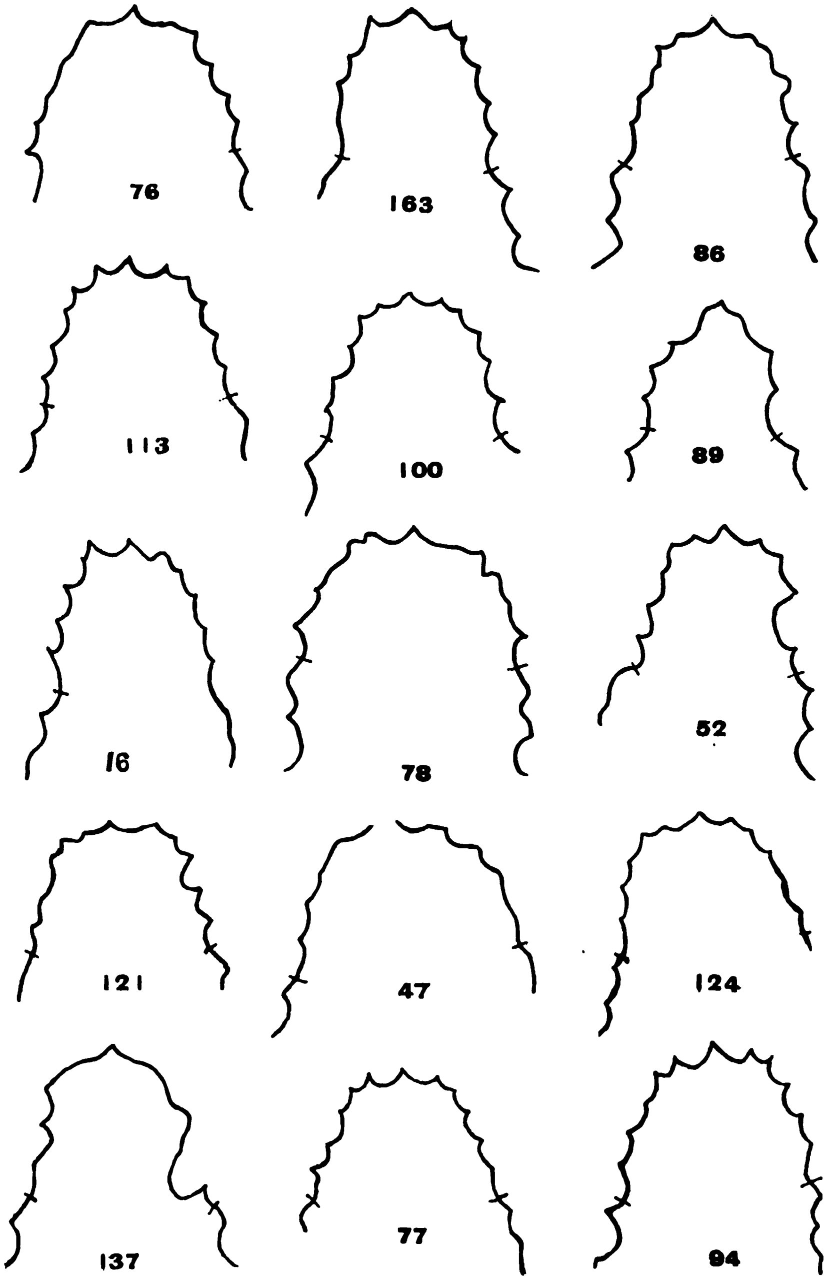
PALATES SELECTED ACCORDING TO FOUR MEASUREMENTS.



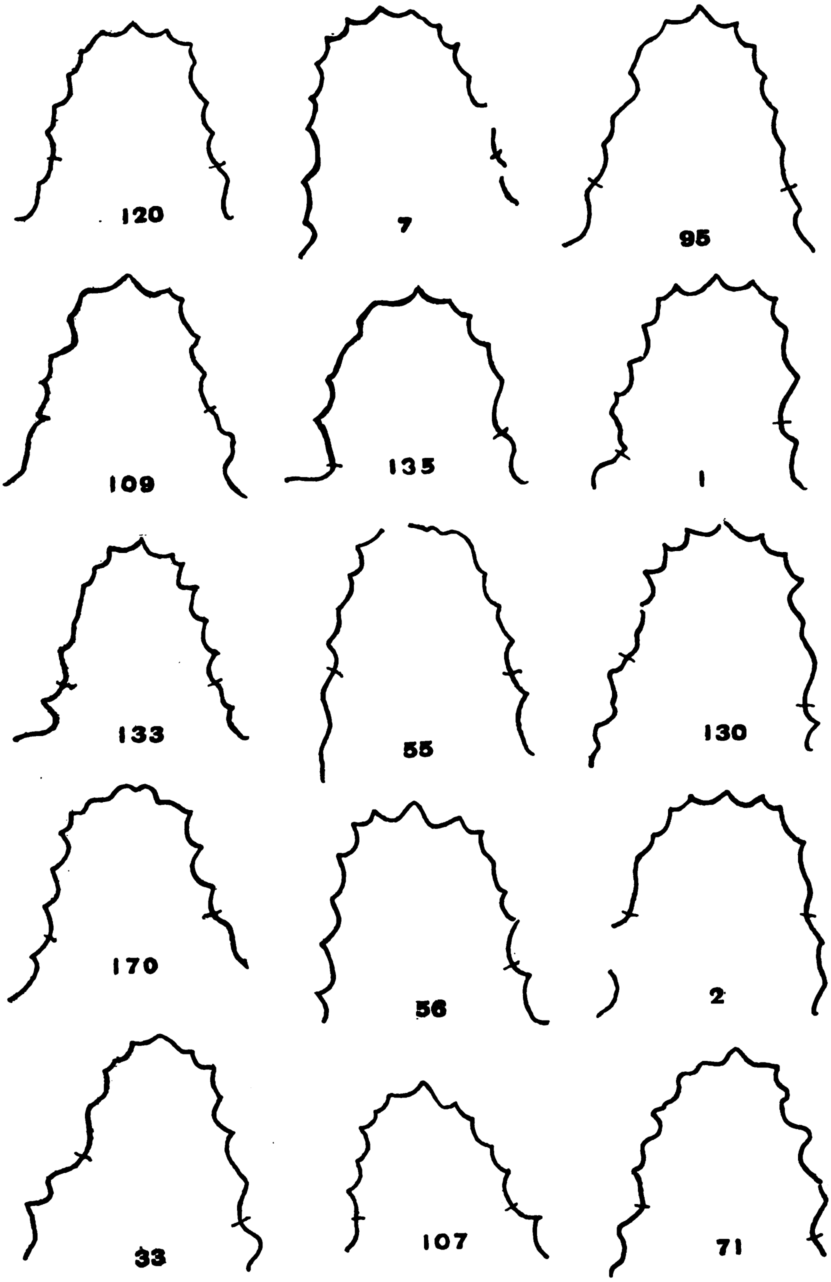
PALATE TRACINGS FROM NINE-YEAR NORMAL-MINDED MALES. (Reduction $\frac{1}{5}$.)



PALATE TRACINGS FROM NINE-YEAR NORMAL-MINDED MALES. (Reduction $\frac{1}{5}$.)



Palate Tracings from Adult Feeble-minded Males. (Reduction $\frac{1}{3}$.)



PALATE TRACINGS FROM ADULT FEEBLE-MINDED MALES. (Reduction $\frac{1}{3}$.)