

ENDOCRANIAL SUTURE CLOSURE ITS PROGRESS AND AGE RELATIONSHIP

PART I.—ADULT MALES OF WHITE STOCK

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HISTORICAL INTRODUCTION

When, in 1641, Thomas Bartholinus republished the lectures and views of his father, he gave us not merely a thoughtful and stimulating treatise on Anatomy fresh, as it were, from the lips of a real investigator but added thereto a synopsis of the current and earlier thoughts upon the subject. For the opportunity to consult first-hand the Fathers in whose writings so much of value is to be found but so largely forgotten through difficulty of approach, this laboratory is indebted to gentlemen like Dr. Weber and Dr. Chamberlin who have presented to the Hamann Museum these rare and valuable sources of information. To return to Bartholinus we find the following stated as the "uses" of sutures (1).

1. To permit free transpiration of the vapors in the brain.
2. For the attachment and suspension of the dura lest it should press upon the soft brain.
3. For the transmission of fibers of the dura through to the pericranium.
4. For the transmission in both directions of vessels carrying nourishment and life to the parts.
5. To diminish the likelihood of fracture of one bone involving also others.
6. To permit more easily the penetration of applications from the exterior.

The hand of tradition is clearly seen in current views upon the sutures when one ponders the six "uses" just enumerated. It is true that number six and to a less extent number five have faded from the modern imagination but numbers two, three and four remain little altered. Number one has undergone considerable change but this change is more in conception of the details than in fundamental principle. We still see the publication of monographs as their theme the relation of early racial closure of sutures to the degree of "intellectuality" and the connection between suture closure and shape of the cranium, both of which ideas can be traced back to the works of Hippocrates. Delightful as it would be to follow out in some detail the development of our present beliefs concerning the sutures, to trace the constancy of these conceptions through the Renaissance to the Anatomists of Antiquity and thereby to realize more fully than we are apt to do the overwhelming influence of tradition, this is really no part of what I have set out to accomplish. I propose to present the facts concerning suture closure and its relation to the racial form and individual contour of the brain-case. Those who desire to study this historical aspect of the problem

cannot do better than consult, by way of introduction, the scholarly work of Pommerol (15) published in 1869.

In brief, although ancient authors like Hippocrates, Aristotle and Galen were acquainted with the fact that some human crania show multiplicity of sutures whereas others are almost or even totally devoid of sutures, dog-like as Aristotle has it, the fact that union occurs during life does not appear in literature until Fallopius attacked the traditional doctrine in the middle of the sixteenth century. It seems probable however that Fallopius was stimulated to make his observations by his great master Vesalius. At any rate there was rebellion in the air against the classical view that sutures have a close relation with skull form for Sylvius who had once been the teacher of Vesalius, Columbus who like Fallopius had been pupil of Vesalius, and Eustachius all shared the view expressed by Fallopius. Very slowly was this new conception assimilated by the majority of Anatomists and a hundred years later the Bartholins agreed that the relation described by the ancients can be found in but rare instances (1 p. 452.).

According to Bartholin the number and site of the sutures, contrary to the assertion of Aristotle, are the same in both sexes, and unchanged, except rarely, by the form of the cranium. To this Diemberbroek, as quoted by Pommerol, added that deformations take place perhaps during foetal life, perhaps at birth. So far back then must we go for the idea of congenital deformity. Gradually after this time the old Hippocratic views upon cranial form faded into obscurity. But curiously enough they were revived by Lucae and Virchow together with the Hippocratic idea of the relation between suture condition and cranial form, although naturally these latter regarded cranial form as influenced by suture closure which is abnormal in point of time. To use the term of Vesalius, the various "figurae depravatae" described by Bartholin return in the classification of these two writers of the nineteenth century. So striking is the similarity between the views of Hippocrates and those of Virchow, allowing for the lapse of time, that Pommerol gives himself up to the picturesque metaphor of the Father of Medicine and the Father of Cellular Pathology meeting each other across the centuries on the subject of synostosis.

Since the middle of the nineteenth century our ideas of the relation between suture closure and growth of the brain have undergone an inversion so that it is now generally recognized that growth of the brain is a cause rather than an effect of the precise date of suture closure. It is not necessary to press the distinction which will of course be under-

stood throughout the further presentation of this theme. Although fully recognizing this change of view the immediate purpose is a study of the sutures themselves and their union. Just as it is no new thought that some relation exists between shape of cranium and union of sutures on the one hand and development of the brain on the other, so also an impression of racial distinction in suture closure is of considerable antiquity. Pommerol points out that Celsus, in his compendium of medical learning in the first century A. D., refers to the teaching, which he it noted antedates Galen, that crania devoid of sutures occur more readily in warm climates (15). This statement was later clarified by Arranius when he asserted the condition to be peculiar to Ethiopians. Here then we have the germ of a belief that suture closure takes place at a relatively early age in Negroes and other "lower" races. No real advance save that associated with Fallopius has been made since these early times. Winslow and others in the eighteenth century emphasized the analogy between sutural membranes and the diaphyso-epiphysial plane, and soon afterwards Soemmering and Meckel pointed out relationship between state of the sutures and development of the brain.

As regards age of suture union it is useless to dissect closely the unprofitable discussions of the last century, based as they were upon altogether inadequate material of which very few skulls were of well attested age. Fallopius had observed that union occurs and Eustachius had noted that it takes place first in the sagittal suture. In the middle of the nineteenth century union had been observed to occur earlier within the cranium than upon the exterior, and in 1856 Gratiolet enunciated his well known laws regarding the earlier union in Negroes and the precise sequence of closure to which we must revert later on (8). During the famous discussion upon volume and form of the brain in 1861 Broca was unable to draw upon any precise data regarding age of closure but observed that many sutures are still patent in men of fifty and even beyond (5 p. 179). Gradually opinion crystallized into a belief that union begins between forty and forty-five years at least in White Stock (e. g. 17), and upon the evidence of a single male skull of forty-six years Pommerol agreed that closure must commence about forty (15). Topinard had Pommerol's work to fall back upon but in addition had observed as closely as possible other material and is more definite. He notes that the period of union for each suture varies considerably but hazards the opinion that if the sutures are yet patent the individual is thirty-five or less, that commencing closure in the sagittal indicates about forty years, in the coronal fifty years, and that if the temporal be

united it indicates an age of sixty-six or more (23). Ribbe in 1885 had fifty skulls of supposedly known age of which forty were those of White Stock. The earliest occurrence of union among these was at twenty-one years and the latest at fifty-five. Taking the mean he concurred that forty to forty-five is the probable average age of commencing closure (16). As regards age identification by suture union Ribbe did not believe it possible to estimate closer than fifteen to twenty years. Dwight set the age of a cranium showing no suture closure at less than thirty years (6). Dwight's material consisted solely of paupers whose ages were apparently not verified. One cannot tell whether, in many of his cases, the statements regarding closure refer to exterior or interior or both. He regarded the date and order of closure as very irregular and not of much value as an age indicator. However he recognized that the same points are not first involved on both sides and that the inner lambda is often patent after all other areas are united.

All the foregoing observations must be regarded as based almost entirely upon external union which may proceed very differently from internal closure. Parsons and Box in 1905 however began to emphasize the significance of internal union (13) and upon this basis they agreed with Dwight.

Frédéric, in 1906, working under the inspiration of Schwalbe who had himself studied this problem in connection with his investigation of the Neandertal skull, made a very comprehensive examination of suture closure in the collection at Strassburg. Frédéric had at his disposal 255 European crania and 119 non-European skulls all of known age. Of these however only 91 European and 13 non-European crania of both sexes were opened so that the internal surface could be satisfactorily examined (7 Table VII.). Frédéric therefore based his conclusions mainly upon the external condition of the sutures of the vault in the unopened cranium. Into the details of Frédéric's observations it is unnecessary to enter here. He decided that it is not possible to determine the age of any skull by the condition of suture union closer than within one decade and hence gives a table (his Table VIII) showing in percentage form the complete closure of each suture externally and the sutures of the vault internally for each decade. This is not very helpful nor is it encouraging. Hence the whole question of the relation of suture union to age remains an intricate and unsolved problem, hopeless alike in the scattered confusion of the data, in the inadequacy of the material utilized and in the unreliability of the information upon which determination of age has been made.

The articles by Pommerol, Ribbe and Frédéric are the main contributions to this subject so far. Each is excellent in its way but all fail to add much to our real information upon age relations, the two former from lack of material and the last mentioned from method of treatment. Parsons and Box, on the other hand, although they had access to but 82 skulls of known age, inspire the greatest hope. They make the very important observation that no estimate of age should be based upon the condition of ectocranial sutures when the inside of the skull can be examined, thereby indicating their opinion that a more definite relation to age might be obtained from a study of endocranial sutures were such a collection of sufficient magnitude available for review. It is at this point that we take up the work.

MATERIAL AND METHOD OF EXAMINATION

From a historical survey of the problem before us it is plain that little real progress has been made and that a proper investigation of the question postulates three necessary conditions. The material must be ample enough to justify it as a sample of the population studied: if both sexes and more than one race or Stock can be examined so much the better. In addition to sex and race age must be known: hear-say will not suffice; there must be some adequate method checking up the given age so that confidence in its accuracy may be inspired. The crania must be cut so that easy inspection of the entire interior is rendered possible. During the past ten years we have endeavored to fulfil these conditions and although accumulation of a satisfactory sample is tedious and difficult I feel that the material which we shall present is adequate for the determination of at least the general features of suture closure.

Drawing upon the crania of more than 1,000 individuals we have rejected all those of which the age record was imperfect or was later discovered to be fictitious, and all those of which the skeleton was not available for comparative study. The series left to us comprises the crania of 307 male Whites, 58 female Whites, 120 male Negroes and 29 female Negroes, a total of 514 skulls all of known age.* It is not suggested that the female crania in the series are of any independent value but even so small a group is useful as a check upon the age relationship shown by the corresponding males. We shall base our conclusions upon the male White series and shall compare with this standard the con-

*NOTE—These numbers refer to the collection in 1921 when this survey was commenced. The numbers are greatly increased now (March 1924.)

ditions found in the females and Negroes. So far as actual numbers go this collection far outstrips any material hitherto available.

It is unnecessary to dilate upon the precise method of checking up the age record of the individual for this has been discussed in a previous paper (19 pp. 289-292) but since that date we have learned to have much greater confidence in the internal evidence of the skeleton itself upon the age problem. As yet little has been published of the great accumulation of data dealing with skeletal age and its significance in Anthropological work. Graves has set forth a preliminary note dealing with the scapula (9) and Stevenson has presented the evidence for epiphysial union (18). These together with my own researches on the pubic bone form merely a beginning for reference. The harmony which is evident among these studies is also to be found in many other investigations not yet ready for the press. Hence it must not be assumed that these alone form the basis of our conclusions. No effort has been spared to obtain complete satisfaction in the question of age which is so fundamental for all our researches. In brief then we may state that from the point of view of age determination the W. R. U. collection is dependable so far as is humanly possible and much more dependable than the vital statistics upon which actuarial investigations for insurance companies are based.

Like our predecessors we have adopted Broca's arrangement of complication of sutures, degrees of closure and subdivision of particular sutures except that we have followed Frédéric in his inversion of Broca's enumeration of the amount of union. Thus, in our records, 0 indicates no union and 4 complete closure: 1, 2, 3, refer to the amount of union, one-quarter, one-half or three-quarters as the case may be. These schemes are set forth in Frédéric's paper (7 pp. 376, 377, 385). We do not differentiate between union which has progressed half-way along a suture and closure which involves a total of half the length of a suture but is exhibited in separate discrete areas. The scheme of Oppenheim dividing sutures into pattern forms and degrees of excursion we have set aside as too involved for practical use (12). The now accepted subdivision of the sutures of the vault is seen at a glance from Oppenheim's figure or Martin's figure 243 (11 p. 627).

To facilitate the accumulation of data we devised a form which can be filed on the card catalogue system and records the type of each subdivision of every cranial suture and the degree of its closure. Separate sheets are used for external and for internal sutures. At the head of each sheet the following general data are recorded: Number of skull,

race, sex, age, greatest length, greatest breadth, cephalic index, cranial capacity, sites of Wormian bones. Thus we had at hand all the information which we felt might be of service in discussing suture closure. The junior author wrote down upon this form the data obtained from our laboratory records and filled in the condition of the sutures and their union. The completed record was then gone over anew by both authors together and the data checked. Consequently the type of suture and the degree of closure are to be understood as the joint observation of two individuals. Where there was any doubt concerning the amount of union the suture was examined under a Zeiss binocular dissecting microscope at ten diameters. It will be realized that the observations are correct only for the external and internal surface of the cranium and we have no accurate information regarding the condition of the suture deep in the substance of the skull wall. The relation between union without and within and between surface and substance must receive special attention, but we believe the condition recorded to be accurate for the surfaces and have spared no pains to this end.

In order to make possible a study of the large and unwieldy mass of data we first reduced to the comparative simplicity of a formula the conditions found in each particular cranium. The following is a typical example showing internal closure of the vault sutures:—

Internal union. Skull 649, male, White, age 22.

Sagittal 1141; Coronal $\begin{matrix} R. 230 \\ L. 110 \end{matrix}$; Lambdoid $\begin{matrix} R. 020 \\ L. 010 \end{matrix}$

This formula should be read thus:—Union of

Sagittal suture—	pars bregmatica	one quarter	pars obelica	complete
	pars verticis	one quarter	pars lambdica	one quarter
Coronal suture—	Right side		Left side	
	pars bregmatica	one half	pars bregmatica	one quarter
	pars complicata	three quarters	pars complicata	one quarter
	pars pterica	none	pars pterica	none

Lambdoid suture—Read for right and left in precisely the same manner as the coronal has been presented.

In the ensuing pages it will be of advantage to refer to special cases for which this formula permits simple presentation.

THE PRELIMINARY SURVEY

Having assembled the evidence in the manner just indicated we took the male White series numbering 307 specimens and plotted out on millimeter paper the degree of union for each cranium, arranging the

series in order of age. This was a very lengthy and tedious piece of work for it involved making a separate graph for each separate part of every suture for the inner and for the outer face of the skull and also for each side of the head. We then averaged the closure for each total suture and plotted right and left side graphs anew. In return for the considerable time spent upon this procedure we expected to be repaid by the convenience thus attained in examination of our data. Nor were we disappointed for, in spite of the individual difference which must be expected, we could see clearly at a glance that there is a definite trend in the progress of closure in relation to age. From these first graphic results we were able to observe roughly the commencement, progress and completion of union in every segment of each suture. It was also apparent that there are marked exceptions in certain skulls to the usual course of union and, passing rapidly from chart to chart we were enabled to note that as a rule anomaly in closure of one suture is associated with anomaly in closure of all. This segregation of anomalous skulls gave us the chance to eliminate them from the final graphs and so define more readily the age relationship of suture closure in the male sex of White Stock. Hence we were able to make a rough preliminary draft of what may be termed the modal type of suture union. The graphs also permitted us to observe that the anomalous instances fall clearly into two classes, quite orderly in their progress, of acceleration and of retardation in suture closure.

The preliminary survey of the male White Stock being completed we undertook a similar presentation of the male Negroes and of the females of each Stock. This led at once to elimination of the instances of abnormal progress in each of these series and gave us a basis for comparison of closure progress in each sex and Stock with our male Whites which we used thereafter as a standard.

Barring exceptions which must receive attention in their turn, it was now clear that there is an orderly age sequence in the progress of suture closure and that sex, Stock, cephalic index and cranial capacity affect this age sequence only in minor degree or not at all. We were forced to the conclusion that far too much has been made of the influence of each of these factors. We could also see that the time linkage is more obvious in the progress of endocranial union than upon the outside of the cranium, thus fully bearing out the helpful suggestion made by Parsons and Box. At this juncture we shall not attempt a discussion of the relative value of closure progress within and without the cranium but content ourselves with the statement that, as a result of our preliminary study,

we have adopted the closure progress of the endocranial sutures of the male White series as our standard for future work. Our initial problems were then, first, the adequate presentation of the modal type of closure progress in relation to age among the male Whites and secondly, the discussion of abmodal progress in this series.

USE OF THE MOVING AVERAGE OR TREND

Realizing the minor difficulties in problems involving age by the arbitrary subdivision of human age into units of one year we resolved to adopt the moving average covering three year intervals as our method of presentation. A few words upon this subject are therefore pertinent. All our graphs, both preliminary and final, are historigrams. That is to say they are numerical records of the degree of suture union (the variable) during successive periods of time, the unit of time being naturally one year. The degrees of union are plotted as ordinates and the age periods as abscissae. Even after the elimination of plainly abmodal instances the graphs were too large and unwieldy for publication for each graph showed precisely the state of closure for every skull in the entire series. The individual differences, though not large, were sufficient to obscure in a measure the general trend of progress. It was necessary therefore to smooth the graphs somewhat. If the total number of observations is relatively small, as must necessarily be the case in an investigation such as this, there may be grave danger of errors creeping in through too vigorous smoothing. We desired in consequence to smooth just as conservatively as we could and therefore we chose to adopt as our basis the moving average over a three year period.

If an individual give his age as say twenty-five years and we have no record of the actual date of birth we must remember that his precise age may be anywhere from twenty-four years and six months to twenty-six years all but one day, according to the individual's own method of computation. Each year of life therefore includes at the maximum eighteen months and successive "years" overlap. Further, as a result of experience, we find that mistakes of one year in either direction are not uncommon in the statements of people in ill-health or under the slightly embarrassing circumstances of being asked personal questions by nurse or doctor. I believe that with difficulties of language the individual error may in certain cases be rather more than one year although there is no means by which this can be corrected. If then we sum up the states of union for all individuals during three successive years of life as given in the records and take the average of these we shall not be far from the

actual mean value for the state of union characteristic of the second of the three years. The plotting of these three year averages will not give an entirely smooth curve for the number of instances naturally varies from year to year in a comparatively small series. We have seen no reliable method by which we could eliminate from our curves the fluctuations resulting from this fact. As I have already intimated the excessive smoothing of graphs built up from a small series is fraught with danger. Our final curves therefore are not smooth but I maintain that the advantages of retaining the irregularities outweigh the possible disadvantages in the present study. In spite of defective smoothing I shall refer to the curves as illustrating the trend of union which in point of fact they actually do.

By the nature of the method the moving average tends to indicate commencement of closure one year earlier than is actually the case and completion of union one year after the date at which all specimens show entire fusion of the suture. It is doubtful however if this is a real error for, as has been demonstrated, the precise beginning of any "year" of life is uncertain and the individual variation seems to extend over a year or two. It is true that during the progress of the work we were considerably impressed by the relatively slight variation from individual to individual and were very suspicious of this observation since it is so strangely at variance with accepted ideas. But Stevenson's work on union of epiphyses confirms us in the belief that in suture closure as in epiphysial union the current expectation of great individual variation is unnecessarily exaggerated. As will be demonstrated in the body of this work a larger acquaintance with the facts regarding suture union forces one to the conclusion that apparent individual deviations from the modal type of closure can usually be explained by accelerated or delayed union which are either phylogenetic or pathological in nature, or by inaccuracy in the age record. I am perfectly aware of the pitfalls of circular reasoning and it will be one of the most important tasks of this work to convince the reader that we have not fallen into one of these pitfalls. At the moment all we can do is to ask indulgence until the full evidence is presented. Although we have come to believe that suture closure, like epiphysial union, once it has commenced, is not normally a long drawn out affair, we are convinced, in view of the facts already presented, that it is safer to use the evidence of the moving average over three "years" regarding the commencement and completion of union than to insert the actual dates given by our present material. Except the sagittal all sutures are bilateral. The moving average for *both*

sides is therefore the basis of our final statements regarding progress of union.

GROUPING OF CRANIAL SUTURES

In discussing the cranial sutures it is convenient to have some grouping by which several related sutures can be included in a single expression. At present the recognized groupings are ill-defined and there is considerable variation according to the particular author in the exact sutures comprised in each group. The older Anatomists grouped the sagittal (and metopic), coronal and lambdoid sutures together as the sutures of the vault and this classification is convenient for our present purpose. Of late however some authors have included the squamosal suture in this group (e. g. Bolk 2). I believe this addition to be unfortunate and that it should not be continued. The older usage will be followed in our presentation. The grouping of the three sutures of the vault (four with the metopic) is merely one of convenience and it will shortly become evident that these sutures are very widely divergent in the significance of their closure progress. As this difference in significance will be shown to be of a phylogenetic nature no further allusion need be made to it at this juncture. It is convenient classification authorized by usage but of no morphological value. Although the metopic may remain open until late in life its appearance is one of the indications of abmodality in suture union and therefore will not be considered by us in our earlier discussions.

There are certain sutures which can readily be classified together into a group which we have found to be closely related to each other in our studies of the phylogeny and growth of the cranium. These comprise in order the speno-temporal, squamous, parieto-mastoid and occipito-mastoid sutures, a group for which Lyon has suggested the descriptive title of circum-meatal sutures. This term will be consistently used throughout our work for it shortly and aptly denotes their relation in phylogeny and growth.

The speno-frontal and speno-parietal sutures form a small group related from comparative and developmental points of view to both the circum-meatal sutures and to the lower coronal. It will therefore be styled the accessory group.

The speno-occipital or basal suture has its own significance and forms a group by itself. Like the metopic it does not enter into the present study since it is already closed before the beginning of adult life. We propose then three groups of sutures with which we must deal, namely

the sutures of the vault, the circum-meatal sutures and the accessory sutures.

In this work we shall take up for consideration the modal and abnormal progress of endocranial suture union as exemplified in the male White series. In later communications we shall discuss endocranial union in its relation to sex and Stock and finally follow out its evolution in phylogeny.

LAPSED UNION

Before beginning a detailed presentation of the results of our study of suture closure it is necessary to discuss a condition by no means uncommon in the sagittal and lambdoid sutures but rarely found elsewhere upon the endocranial aspect. This condition I shall term lapsed union. It is characterized by apparent failure of union over a greater or smaller part of the suture accompanied by a heaping up of bone tissue along the edges of the unclosed part. While bone along a suture margin is still in a state of activity it presents a well defined granularity of texture very difficult to describe but none the less easily recognizable. After activity has ceased the granularity gives place to a smoothness of texture which can be likened roughly to a waxy surface. The heaped up bony margins of a suture in the condition to which I refer show this characteristic evidence of quiescence which absolutely differentiates them from the margins of a suture still in a state of active closure. The condition is not limited to Man; all mammals show the same features. There is no doubt that such sutures have been classed as patent by previous investigators and owing to this misinterpretation of the state of the suture unnecessary confusion has been injected into the age relationship of suture closure. Just why the condition develops in the sagittal and lambdoid sutures of all mammals is not yet apparent but it must nevertheless be reckoned with and discounted. A suture in this condition is unlikely to close to any greater extent. In our observations we have marked the condition by an asterisk and when we came to assemble our results we found lapsed union accounted for many of the apparent anomalies in closure of the lambdoid suture and for the greater proportion of anomalies in the sagittal. Such sutures have therefore been classed as united.

This condition of lapsed union is by no means confined to the cranial sutures. It occurs not infrequently at the junction line between epiphysis and shaft in the long bones particularly at the upper end of the tibia and the head of the femur. But by far the most frequent appear-

ance is at the line of union between the epiphysis for the iliac crest and the body of the ilium. Dr. Stevenson's work upon epiphysial union demonstrates that fusion of this epiphysis is really of considerable value as a time marker once one learns to discount the appearance of lapsed union. In his description of skeletons for the Nubian Survey Wood Jones refers to the "long delay" which the union of this epiphysis with the ilium presents especially at the hinder end (24 p. 256). Undoubtedly such cases should be classed as lapsed union.

In dealing with differentiation in the pubic bone I have shown that a condition akin to lapsed union is not uncommon in the building up of the ventral margin and upper extremity especially in White Stock (19 p. 308). It results from failure of complete ossification in the epiphysial mass on the pubis. I have also shown that the condition is present in other mammals (20 p. 414).

The peculiar features of lapsed union or lapsed ossification are always the same and are readily appreciable once their significance is understood. It would seem as though Nature grew tired sometimes of carrying on her morphological work to its completion and left the structure imperfect in appearance though not in function. The discounting of lapsed union is an important part of the interpretation of both epiphysial and suture closure.

PART I.—MALE ADULTS OF WHITE STOCK

THE DETERMINATION OF MODAL PROGRESS

The 307 skulls comprised in the male White series of known age are those finally chosen as suitable for the present work since there is no reason to dispute the record of their ages and the entire skeleton is available for study. But since these skulls are spread over the life period from eighteen to eighty-four years inclusive, relatively few belong to each year and in the later part of life there are gaps of a few years without skulls. Despite this inevitable drawback the series is representative and consideration of its members inspires confidence that no essential part of the story of suture closure is defective. The collection is constantly growing and now is considerably larger than it was when the final choice of the series was made more than three years ago. Although we have been unable to include the additions in the standard series our confidence in the essential accuracy of this series is in no way impaired.

At first sight the number of skulls belonging to any particular decade

may seem perilously small upon which to build a statement of suture union so dogmatic as we are about to present but it must be remembered that the skulls belonging to the period during which union actually occurs are not to be considered as alone in presenting the evidence. They determine only the progress of union once it has begun. The uniform absence of closure in the particular suture in question in all skulls below the age of beginning union and the equally uniform occurrence of complete closure, barring occasional lapsed union, in all skulls beyond the age when completion of closure takes place, are the evidence which delimits the period of actual union and gives point to and confidence in the statements relative thereto.

In attempting to ascertain the modal progress of closure it is obvious that we should meet with exceptions to the rule. Already in our preliminary graphs in which all 307 skulls were represented the general trend of progress was sufficiently clear to us with our knowledge of the skeletons included in the series. But it was equally apparent that some skulls showed more, some less deviation from the rule. Variability in Man and particularly in the skull, prepared us for this. But the proper elimination of the variant skulls presented a very difficult problem. We had to devise some test which should not be directly related to suture closure itself, a test which should determine upon general skeletal grounds whether or not a skull ought to be retained in the first formulation of modal progress. A problem of somewhat similar character was presented in the survey of pubic symphyses which ultimately resolved themselves into three types, better marked it is true in the Negroes but nevertheless quite apparent also in the Whites. The essential feature of the pubic subdivision is the fact that certain human symphyses show their anthropoid origin more clearly than others. I have therefore spoken of the anthropoid strain of symphysis and of the regressive form (21). The latter type is more numerous than the former and therefore more characteristically human. It appeared possible that in this subdivision we had a means of separating skeletons into groups without reference to the skull and still with some reasonable hope of finding a resultant effect upon the graphs of suture union.

Between the anthropoid and regressive symphysial types there occur certain symphyses, relatively much less numerous than either of the other groups. The exact position of these it is difficult to determine. Many are certainly retrogressive examples of the anthropoid strain, nevertheless this form is properly intermediate between the other two. Now it is characteristic of the anthropoid strain that the pubic age re-

relationships fall nearer to those of the Giant Anthropoids and there is also a clear difference in age-relationship of the skeleton between human beings according as they exhibit the anthropoid strain or the regressive form of symphysis. The great mass of evidence for this assertion must await its turn for publication; at the moment we will have to accept it as a postulate. Upon this basis we first of all cut out from our series all the skulls belonging to skeletons of the anthropoid strain. Immediately the graphs of suture closure reacted in a very remarkable way for most of the skulls eliminated exhibited an unusually advanced state of closure for their age. Naturally this sweeping reduction seemed to take out some specimens which we would rather have retained but we feared to meddle with the working of the plan on which we had decided.

In my investigations upon the symphysis I demonstrated that there are some skeletons which show an accelerated type of differentiation (metamorphosis) and others in which differentiation is undoubtedly retarded. At the very beginning of the skeletal work these gave considerable worry and caused me to doubt gravely the accuracy of our age records. After a close investigation I was convinced of the essential accuracy of these records and collateral evidence assured me that there is a variable age relationship in the skeleton just as there is in other tissues and in the external features of the individual. As I have pointed out this acceleration or retardation has no relation to the type of symphysis (21). Either condition may and does occur in anthropoid strain or regressive form. Hence our next step was to eliminate all skulls belonging to skeletons which exhibit a marked anomaly of skeletal age-relationship.

For several reasons this further step was necessary. In the first place elimination based upon an anthropoid strain in the pubic symphysis affects only skeletons of the third decade. As a matter of fact it was among the skeletons of this decade that we were most in need of guidance. But for later decades we had no method of elimination upon which we felt that we could rely except the general one of skeletal age-relationship. In a very valuable and unique piece of work Bolk has shown that there are skulls which exhibit partial or complete closure of certain sutures, notably the sagittal and masto-occipital, at an early age (3, 4). In these skulls the union probably occurs entirely or for the most part before the age of seven years. We must expect to find such skulls among our series also and it is probable that, had Bolk been able to examine the entire skeletons of the children, he would have found other evidence of an unusual precocity in bony differentiation. At any rate,

upon these grounds, we felt safe in making a further elimination upon the following basis.

Bolk's remarkable findings in children's skulls lead one to suspect that there may also be a type of skull in which the closure of sutures is very long delayed or never takes place. As a result of our investigations we believe that the latter condition does occur. We therefore eliminated all skulls which we felt perfectly certain belonged to Bolk's precocious group and also those of this antithetic class.

As the result of these drastic reductions our material grew very small but at the same time remarkably uniform and harmonious in the information it now gave regarding suture closure. From this greatly restricted material we were able to discern clearly the real direction and relations of the curve of closure. The method employed is the same in principle as the one which I used to make my original estimates of age-relationship in symphysial differentiation (metamorphosis) but in that work determination was a much more prolonged and oftentimes a very discouraging process for, incidentally, so much of the basis of our skeletal work had to be laid before reliable results could be obtained for any portion of the skeleton. This basis is now built up in large measure though by no means complete but it seems probable that features of differentiation slowly and with difficulty gathered in the earlier researches will be of the greatest advantage in guiding and safeguarding the interpretation of other parts of the skeleton successively studied.

Having then obtained upon a very restricted but methodically selected material the essential data for closure of the sutures we next set about reclaiming in a guarded manner some of those specimens which we had lost. When however we finally reject a skull it must not be imagined that our guide has been simply the state of closure of the particular suture in question or yet of the sutures in general; the reason has always been a very definite one, based upon evidence in the skull or elsewhere in the skeleton of some anomaly which would give us pause, at this period of the investigation, in laying weight upon its evidence, however favorable this evidence might be to the special problem under consideration.

In reading of the method of elimination and selection of our crania it may well be wondered why we have paid no attention to the view of Ribbe that there is a significant difference in order of closure of sutures in dolicho- and brachycephalic skulls. The point will be discussed more fully later. Suffice it for the moment to state that we have found no evidence whatever of any truth in the assertion. It must also be re-

membered that Gratiolet made a distinction in order of closure between higher and lower races of mankind. What constitutes a higher and what a lower race may be open to considerable question. But it is generally agreed that the negroid races belong to the lower group and certainly it is what Gratiolet had in mind when he penned this sentiment (8). Evidence upon the subject will appear from comparison of our results on Negroes with those on Whites. Certainly there can be no differentiation between higher and lower races so far as Whites alone are concerned. We shall later have something to say upon the validity of the argument touching White idiots.

THE SAGITTAL SUTURE.

(Figs. 1 & 2)

The averages for the several parts of the sagittal suture have been gathered together into one graph from which the mean progress of the entire suture may easily be read. It is shown along with similar curves for the coronal and lambdoid sutures in Fig. 1. One should read this graph and that showing union in constituent parts of the suture (Fig. 2) at the same time. To avoid a disjointed statement we shall discuss them together. Union begins at twenty-two years or slightly earlier in the obelic part, spreading by the end of the twenty-third year to all other parts of the suture. In the obelica closure progresses rapidly to its completion at twenty-nine. In the other parts union does not gather speed until the end of the twenty-sixth year when it takes a spurt forward and has already reached the stage of closure represented by 3.5 at twenty-nine years. By thirty-one closure is almost complete in these three parts but the terminal stage is delayed until thirty-five.

The obelica then runs a course by itself and the other three parts of the suture form a harmonious group with a rather different age relationship in closure progress.

Fig. 1. naturally gives the average of all four parts and since there is marked distinction between the curve of the obelica and those of the other parts the composite curve reflects in certain degree the characters of both types. The very gradual rise of the curve just before twenty-two years is the effect of the early obelic commencement. Thereafter the composite curve follows fairly closely the curves of the three other parts which easily overpower the obelica in the final average. The composite curve is more difficult to interpret than those of the constituent parts which we might call the analytic curves: it gives only a general indication of the precise trend. But its particular value lies in the fact

ENDOCRANIAL SUTURE CLOSURE

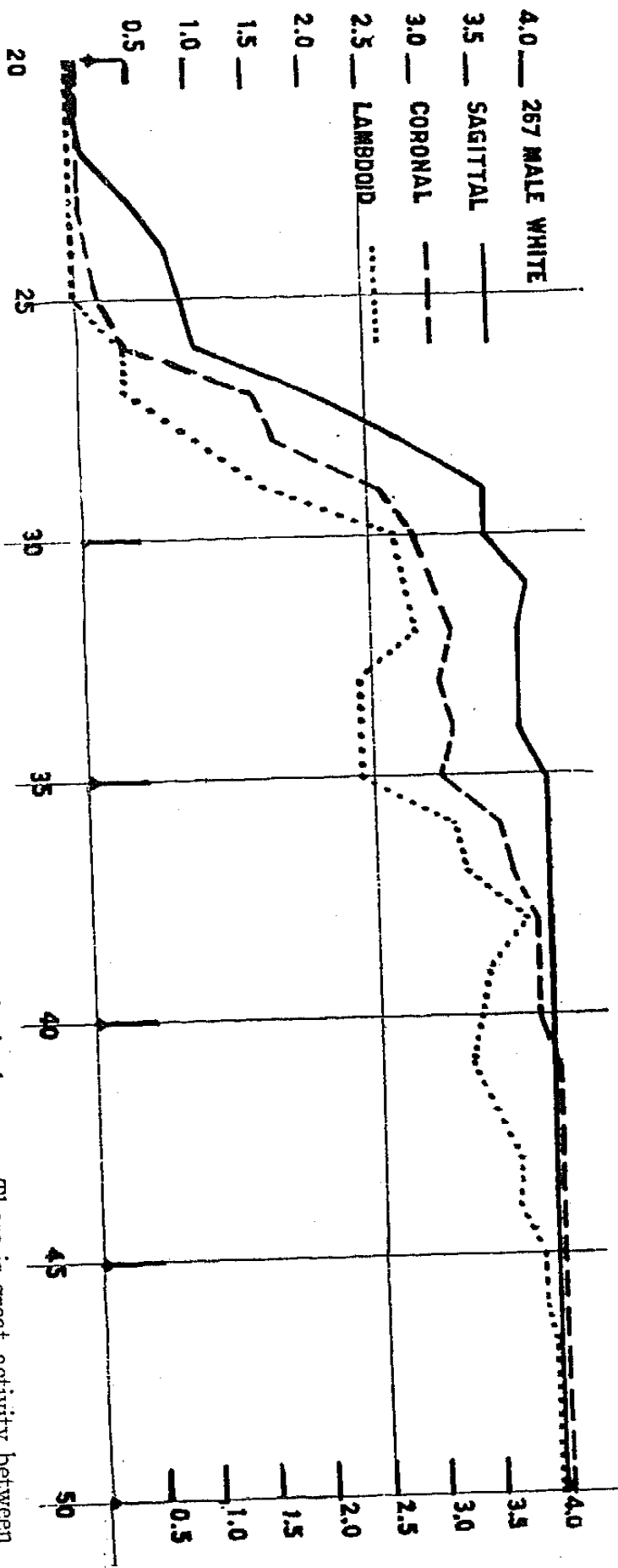


Fig. 1. Endocranial closure progress in the sutures of the vault. The relative order is shown. There is great activity between twenty-six and thirty years but lethargy before and after this period.

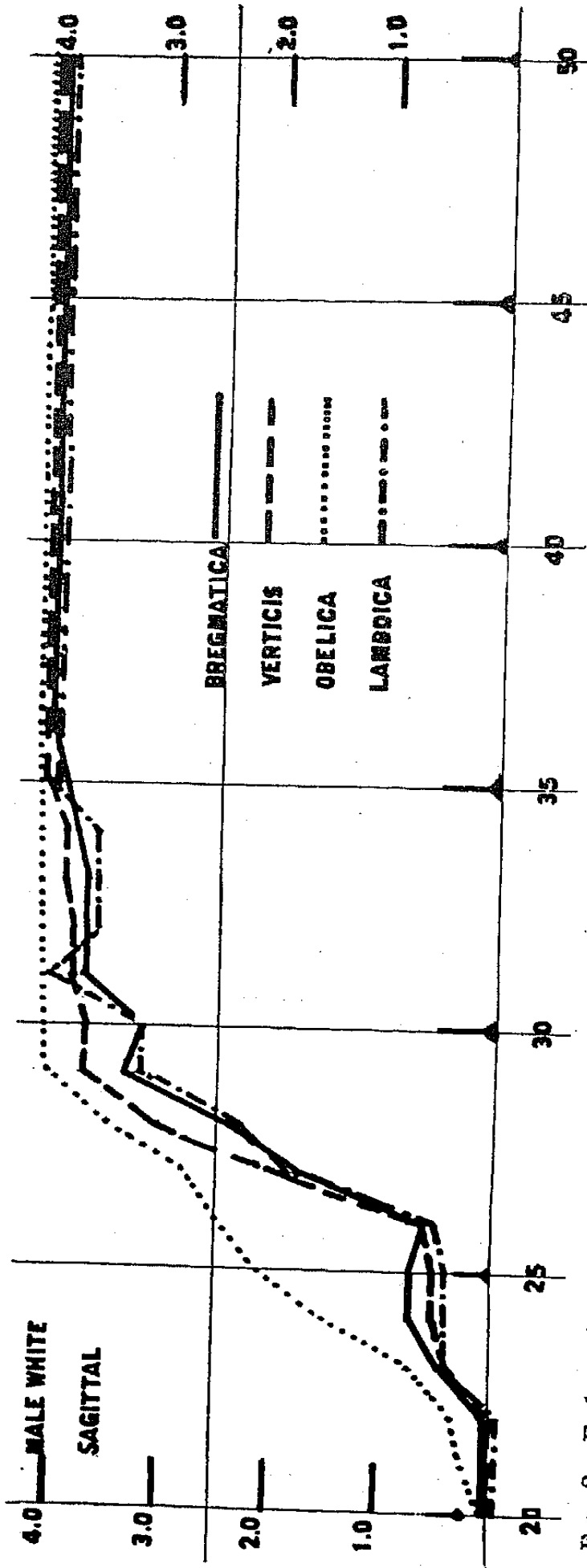


FIG. 2. Endocranial closure progress in the sagittal suture. The pars obelica has a progress of its own rather different from that exhibited in the other segments.

that it is so sensitive to initial and terminal changes. It must commence to rise as soon as any part of the suture has really begun to unite and it cannot reach completion until the last part of the suture is actually closing.

The difference between the curve of closure of the obelica and those of the remaining parts (the B. V. L. curves) is quite obvious but its significance is not entirely clear. Neither the curve of the pars verticis nor that of the lambdica at all approaches it in form. Of course one may assert that it is a primitive part of the cranium associated with the parietal foramina, but this is no satisfactory explanation. The relation of the foramina to the obelica varies greatly in different individuals. We must admit that so far no adequate reason for this peculiarity has presented itself.

The similarity in the curves for the partes bregmatica, verticis and lambdica is just as striking in its way. The pars verticis and the pars lambdica are separated by the obelica and yet the courses of union in the two run closely parallel. The initial lethargy and the terminal delay observable in all are not particularly features of the sagittal suture; they are rather a skeletal characteristic for the years during which they are exhibited. As such they will be observed again and again and must receive attention later.

The main features of closure progress in the sagittal suture can be briefly set forth in the following manner.

Male White endocranial closure commences at twenty-two years with (a) a gradual rise to 1.0 at twenty-six, (b) a sharper rise to 3.9 at thirty-one, (c) a terminal oscillatory delay with (d) complete union at thirty-five years.

No skulls of thirty-five or over, excepting instances of lapsed union, fail to show complete closure. The critical period between twenty-two and thirty-four years is represented in the collection by forty-two skulls. The tabulation of the entire series with reference to closure of the sagittal suture is the following:

Age	Period	Number of skulls	
		Retained	Rejected
18-21	pre-(a)	4	0
22-25	(a)	11	2
26-30	(b)	16	6
31-34	(c)	15	1
35-84	(d)	221	31
Total retained in series			267
Total rejected			40
Grand total			307
Percentage of discards to grand total			13.3
Percentage of discards (a)-(c) inclusive on total of this period			17.6

The value of this table lies in the ease with which one can judge from it the reliance to be given to the conclusions drawn from the survey. The total retained in the series, the total rejected, the grand total and the percentage of discards to the grand total remain the same throughout the survey of all sutures except the lambdoid. Why we have found it necessary to make changes in the survey of the lambdoid will become clear in discussion of that suture after presentation of ectocranial closure progress.

It is in the pars verticis that one finds lapsed union to occur most frequently. Here actual complete closure may be long delayed and indeed it is even possible that it is never completed in some individuals. These instances of lapsed union must not be permitted to confuse the real issue. They are comparable to the cases in which symphyseal outline remains incomplete throughout life. They are readily recognized by the heaped up character of the bone along the margins of the suture. The examination of a score of skulls thirty-five years old and over will give far more confidence than pages of description in reading correctly this feature. The same condition is found especially in the lambdoid part of the lambdoid suture and occurs in other mammalian crania.

In examining critically the table of numbers of skulls used the first objection is the small number in the series before union begins in the sagittal suture. Bolk's series of 1820 juvenile skulls ends just at the age when our series commences and of this great number only 71 showed partial or complete obliteration of the sagittal suture. It is therefore clear that we have been able to plot the modal commencement correctly. The second apparent defect is the small absolute number of skulls upon which we base our determination of actual closure progress. That we have really obtained a correct record of the length of time over which the progress is spread before union is completed is evident from the fact already stated that none of the 221 skulls of over thirty-four years, barring always the instances of lapsed union, exhibits imperfect closure. These two limits of the progress of union being ascertained it cannot well be objected that our curves do not give a reasonably correct idea of the course of union during the time when it is in progress for whereas we have retained forty-two skulls we have rejected only nine. Nevertheless it is important to give the reasons for rejection of these discards. The condition of the endocranial sutures of the vault in these nine skulls can be obtained at a glance from the following table of their closure formulae. The reader will find directions for reading these formulae on page 332. They should be considered alongside the graphs of modal closure progress in the three sutures (Figs. 2, 3, 4).

Age 22.	No. 649.	Sagittal 1141; Coronal	R. 230	; Lambdoid	R. 020
			L. 110		L. 010
			R. 444		R. 344
Age 24.	No. 667.	Sagittal 3333; Coronal		; Lambdoid	
			L. 444		L. 342
			R. 000		R. 000
Age 26.	No. 653.	Sagittal 0000; Coronal		; Lambdoid	
			L. 000		L. 000
			R. 000		R. 000
	No. 490.	Sagittal 0000; Coronal		; Lambdoid	
			L. 000		L. 000
			R. 000		R. 000
Age 27.	No. 317.	Sagittal 0000; Coronal		; Lambdoid	
			L. 000		L. 000
			R. 000		R. 000
Age 28.	No. 94.	Sagittal 0042; Coronal		; Lambdoid	
			L. 000		L. 000
			R. 440		R. 441
Age 29.	No. 436.	Sagittal 4444; Coronal		; Lambdoid	
			L. 441		L. 441
			R. 000		R. 000
Age 30.	No. 238.	Sagittal 0000; Coronal		; Lambdoid	
			L. 000		L. 000
			R. 444		R. 000
Age 34.	No. 301.	Sagittal 1144; Coronal		; Lambdoid	
			L. 144		L. 000

Three of them, Nos. 649, 667 and 436 were originally thrown out as belonging to skeletons in the category of the symphysial anthropoid strain. All show plain anomalies of suture closure and, unlike certain others of the anthropoid strain, have not found their way back into the regular skull series. It is probable that we would not have dared to eliminate No. 649 on the basis of the sagittal suture alone but the condition of its coronal and lambdoid sutures renders uncertainty impossible. The other two are cases of precocious union such as Bolk found. One would not care to hazard at this stage of the investigation just when union did take place but it may be recalled that Bolk found it to occur usually by seven years.

The other six specimens deserve a somewhat fuller consideration.

No. 490 age 26, shows no endocranial closure of the vault sutures. There is obviously therefore some retardation in cranial differentiation. The symphysis is in phase IV but is an example of the intermediate type. Hence the skeleton is one in which anomalies might justly be expected.

No. 317 of age 27 required explanation in the symphyseal work (19, p 316). The skeleton is that of a rachitic dwarf who showed extreme kyphosis and many anomalous conditions resulting from retarded development. It is to be expected therefore that the cranium would also show markedly retarded differentiation.

No. 94, age 28, is a case of extremely anomalous symphysis. It shows no closure whatever endocranially of the coronal and lambdoid sutures or of the bregmatic and vertex parts of the sagittal. The obelic part is completely closed and the lambdoid half closed.

Nos. 238, age 30, and 653, age 26 show no endocranial closure of these three sutures. The latter has a symphysis of the anthropoid strain, the former of the regressive type in phase VI. We have in these two specimens a condition where deficiency in cranial suture closure seems at variance with the state of the symphysis.

The same is true of No. 301, age 34, but this cranium is easily seen to be anomalous and no reference is needed to the entirely modal symphysis in phase VI. The bregmatic and vertex parts of the sagittal and the bregmatic part of the left coronal are only one-quarter closed while the other parts of sagittal and of both coronal sutures are fully united. The lambdoid suture is completely patent on both sides.

In summary of the nine discards we note that three show a condition of precocious suture closure harmonious with the state of the symphysis; three exhibit retardation of suture closure associated with retardation or anomaly of the symphysis; and three only present such divergencies in skeletal time relationship that they require further study for their elucidation.

The absolute lack of union in any of the vault sutures characteristic of several of the foregoing rejects is not so striking in the third decade as it becomes later in life. Had it not been for the facts that we have been able to examine the entire skeleton and that we possess records regarding age which we believe above suspicion we dared not have eliminated these. At the moment it is necessary to point out that if sutures are to remain patent throughout life or the greater part of it some of these anomalous skulls may be met with in such an age period as this when identification of the anomalous specimen by the skull alone would be a sheer impossibility. The determination of these skulls as unacceptable must be made upon the rest of the skeleton. This is one of the reasons for retaining in our series of skulls of known age only specimens of which the entire skeleton could be studied.

THE CORONAL SUTURE

(Figs. 1 and 3)

In dealing with the sagittal suture we had a comparatively simple problem for its position in the median sagittal plane postulates for it a relative harmony of influences impossible to assume for a bilaterally symmetrical suture like the coronal or lambdoid which bear so very different a relation to the median plane of the body. Reference to the graph of the entire suture (Fig. 1) shows that in commencement and in completion of union and therefore in the whole course of its closure the coronal suture lags somewhat behind the sagittal. This fact is well known and with this statement previous authors have generally been content. But the analytic graph (Fig. 3) showing the closure of the individual parts of the suture gives a very different conception of the progress of union in the suture. Omitting the pars obelica of the sagittal which is a law to itself, one cannot fail to be impressed with the general similarity of the curves of closure in the three other parts of the sagittal with those of the partes bregmatica and complicata of the coronal. Although these latter commence to unite rather later than the sagittal their curves of closure rapidly catch up and by twenty-nine years the degree of union is the same in both groups. Thereafter the curves run along practically parallel, final completion being somewhat delayed in the coronal. For the pars pterica the progress of union is quite different and it is obvious that it is the radically different course of this part which, when averaged in with the others, brings about the apparently simple lagging in union compared with the sagittal in the graph of the entire coronal suture.

Considering then first the partes bregmatica and complicata together we note that union commences at twenty-four years, quickly gathering speed and reaching the point indicated by 3.4 at twenty-nine. From this age onward closure proceeds more slowly and with oscillations. Complete closure, that is to say, attainment of 4.0 by the curve finally occurs at thirty-eight years.

The facts may be presented thus:—

- Male White endocranial closure commences at twenty-four with
- (a) a gradual rise to twenty-six, after which
 - (b) a steeper rise till twenty-nine years, and then
 - (c) a much slower and more erratic progress towards
 - (d) complete closure at thirty-eight years.

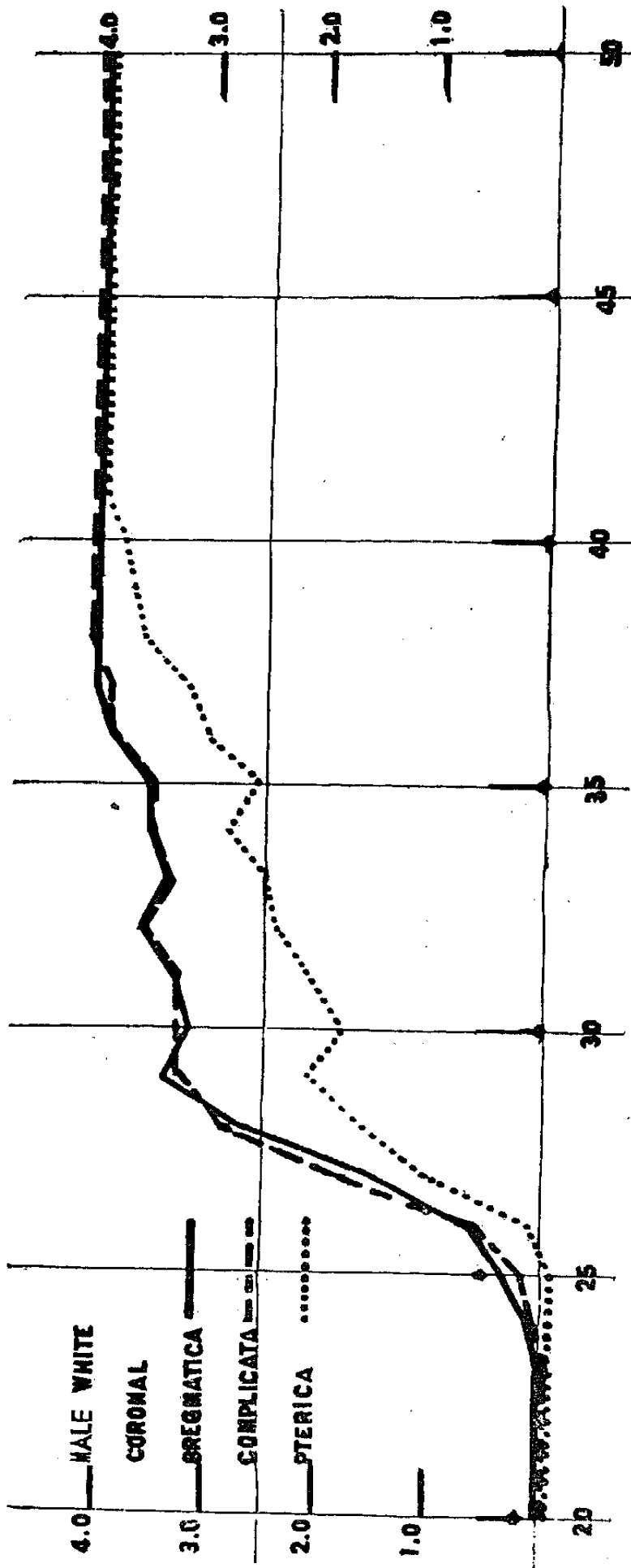


FIG. 3. Endocranial closure progress in the coronal suture. The pars pterica has a special closure progress dictated by its position in the cranium.

The table of closure is the following:—

Age	Period	Number of skulls	
		Retained	Rejected
18-23	pre-(a)	9	1
24-28	(a)+(b)	14	5
29-37	(c)	46	7
38-84	(d)	198	27
Percentage of discards (a)-(c) inclusive on total of these periods			16.7

The critical period of closure (a)—(c) of the coronal suture is represented in the collection by 72 skulls of which 12 are rejected as abnormal. The extent of deviation of all discards under thirty-five years has already been shown so that we have now only to note the condition of the four rejected specimens between thirty-five and thirty-seven years.

The state of closure of the sutures in these specimens may be read at a glance from the following tabulation.

Age 35	No. 242.	Sagittal 0000; Coronal	R. 243	R. 000
			L. 244	L. 000
Age 36.	No. 445.	Sagittal 4242; Coronal	R. 443	R. 100
			L. 444	L. 000
	No. 767.	Sagittal 0000; Coronal	R. 021	R. 030
			L. 022	L. 043
Age 37.	No. 385.	Sagittal 0144; Coronal	R. 000	R. 000
			L. 033	L. 000

Compared with the usual sequence and times of closure there is sufficient irregularity in each of these to justify its exclusion.

It is at once apparent that irregularities in closure of the coronal suture, while obvious enough, are not so striking as in the sagittal and lambdoid sutures. The condition of the upper part of the suture tends to approximate to the degree of closure in the bregmatic part of the sagittal but this is only a general tendency. The trend of the coronal suture is towards delayed union rather than in the direction of precocious closure. Among his 1820 juvenile crania Bolk found premature obliteration of the coronal suture only twelve times against seventy-one instances for the sagittal.

The simplicity in pattern of the endocranial aspect of the coronal suture is very striking when the complexity of the ectocranial aspect is borne in mind. Into this question we do not propose to enter in this paper. The problem has been discussed by various authors and with their conclusions we shall deal upon another occasion. At the moment

it must be impressed upon the reader that the degree of ectocranial complexity upon which the suture is subdivided into its three constituent parts is of no significance for endocranial closure. One must dissociate these two problems for it is sufficiently apparent from our graphs that the bregmatic and complicated parts of the suture are really closely related in their endocranial closure whereas the pars pterica forms a part of another system of suture union with which we shall deal later.

The sixty modal crania comprised in the critical period of union form a singularly harmonious group. The regularity of their closure progress on the endocranial side in spite of the marked difference in ectocranial pattern between bregmatic and complicated portions (Fig. 3), and the symmetry in closure of the two sides are apparent from the preliminary analytic graphs (not published). The right side, if anything, lags a few months behind the left but it would not be wise to lay any stress upon the very slight differences in these curves. Again the bregmatic and complicated portions present almost the same pattern in their closure curves, the one being practically superposed upon the other.

These facts may be presented in the following manner:—

Pars.	Side	Closure commences at	Closure completed at
Bregmatica	Right	24	37
"	Left	24	37
Complicata	Right	24	38
"	Left	24	36

ENDOCRANIAL CLOSURE OF THE PTERIC PART OF THE CORONAL SUTURE

We have already sought to justify exclusion of the pteric part in our consideration of the major part of the coronal suture. The reasonableness of this action will become more and more apparent as the discussion proceeds. But for symmetry of presentation the facts concerning the pars pterica should be stated at once.

Closure commences at twenty-six years with a fairly sharp rise until twenty-nine when the curve begins to climb more gradually. At this age the curve stands at 2.1. Barring a few oscillations the rise after this age, though slower, is fairly steady until complete closure is attained at forty-one. Reference to the graph (Fig. 3) will render more obvious the lagging of closure in this part of the suture behind that of the complicated and bregmatic regions. Its precise significance will receive attention later.

A summary of the facts may be presented thus:—

Male White endocranial coronal closure (pteric part) commences at twenty-six with

- (a) a fairly sharp rise to twenty-nine, after which
- (b) a more gradual but still steady rise to
- (c) complete closure at forty-one.

Age	Period	Number of skulls	
		Retained	Rejected
18-25	pre-(a)	15	2
26-28	(a)	8	4
29-40	(b)	77	17
41-84	(c)	167	17
Percentage of discards (a) + (b) on total of these periods.....			19.8

The chief difference between closure of this part of the suture and closure of the other parts is the delay in commencement and in completion. It seems as though some factor begins at twenty-nine to exert a retarding action upon union throughout the entire suture and since, at this age, the pterica is already behind the other two it remains laggard in its progress. It would be exceedingly difficult to understand this delay both in commencement and in completion if the pars pterica were considered apart from closure in the cranial sutures as a whole. Later on in this presentation it will become apparent that this delay is not an accidental character but falls exactly into line with the closure progress of a suture complex other than that to which the upper part of the suture belongs.

There seems to be some evidence, not however very assuring, that union commences on the right side rather earlier than on the left but in spite of a tendency towards somewhat earlier completion on the right, this advantage constantly passes from one side to the other. We incline therefore to regard the evidence as equivocal and to consider closure progress as symmetrical.

THE LAMBDOID SUTURE
(Figs. 1 and 4)

The lambdoid, according to the graph of the entire suture, closes later than either the sagittal or coronal and this delay is appreciable throughout its course from commencement to completion. There is in this graph no indication of cephalic index. The discussion of a possible relation of shape of skull to suture closure awaits complete presentation of the data for closure in general. Gratiolet described the order of union as sagittal, lambdoid, coronal. He was opposed by Cruveilhier and

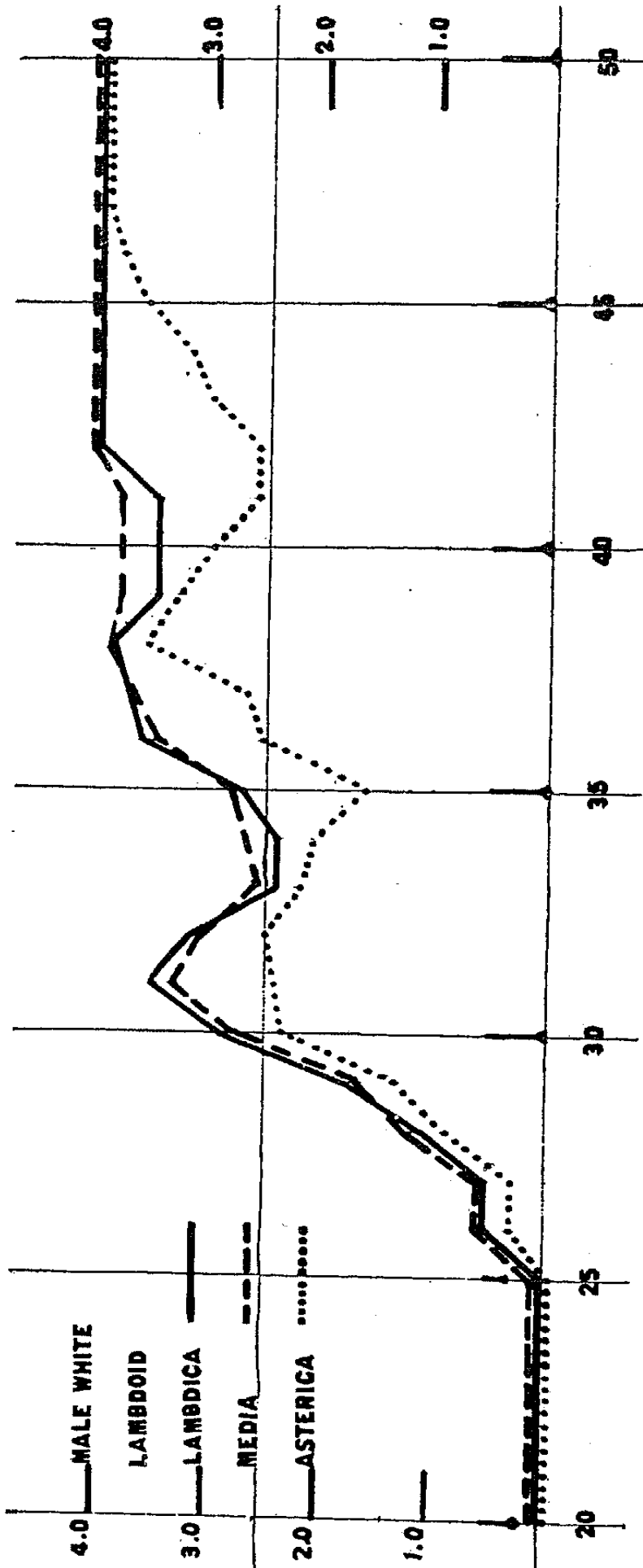


FIG. 4. Endocranial closure progress in the lambdoid suture. All parts show a period of great activity between twenty-six and thirty years. A noteworthy lethargy is exhibited after this phase.

Sappey according to whom the coronal unites before the lambdoid. Meckel and Pommerol also agreed that the coronal closes first. Ribbe objected that Pommerol's cases were too few to justify any conclusion, and himself stated the order for Parisians as sagittal, lambdoid, coronal. Ribbe also allows that the coronal is involved before the lambdoid in one out of three cases. Frédéric found the lambdoid to unite internally after the coronal, the pars media even closing before the pars lambdica. Parsons and Box believe that the lambdoid closes later than the coronal as a rule. All these observations except Frédéric's are based upon the ectocranial sutures, a problem more complex than that of the endocranial aspect. Our graphs (Fig. 1) show that there is little difference in the age relationship of union in the two sutures but that on the moving average the coronal suture does unite before the lambdoid. There are however stages where both curves reach the same point. I have previously shown how inadequate is the general graph to indicate the real course of closure and how actually misleading it may be. The real comparison should be made between the analytic graphs of the two sutures.

The actual differences in closure between the coronal and lambdoid sutures lie in certain facts. In the coronal the pars pterica has a closure progress different from that of the other parts of the suture. This, averaged in the entire suture, drags down the curve. In the lambdoid all three parts are in fairly close harmony up to thirty years. Beyond this date all are delayed and erratic, the pars asterica more than the other two (Fig. 4). The assertion that the lambdoid may close before the coronal does not hold for the endocranial aspect and it is only when the pars pterica is averaged in with the rest of the coronal that there might be any confusion regarding which suture exhibits the greater degree of closure. In coming to this conclusion one must of course discount lapsed union which occurs not infrequently in the pars lambdica. It is largely due to the failure to recognize this condition of lapsed union that previous workers have become confused in their interpretation of the order in suture closure.

At this point one must say a word regarding the fundamental difference between the investigations now being presented and those which have gone before. Until we gathered the accurately dated material in the Hamann Museum no one possessed a sufficient collection of skulls of known age to justify the interpretation of suture closure upon its age relationship. That this is possible for us is due to the fact that we have been able, in addition to the actual age records, to secure internal evidence upon other parts of the skeleton which convinces us that we are in reality dealing with a problem soluble only upon age characters.

In the researches of earlier investigators the age relationship could not be relied upon. There was therefore nothing to fall back upon except the average closure over a large number of adult crania of unknown age. This method naturally involved the concept of a closure tendency. Some sutures or certain parts of sutures show, in the mind of investigators, a greater tendency to close than others. It is easily seen that once the idea of a closure tendency is adopted the alternative concept of an age relationship recedes further in the mental picture until it becomes negligible. Add to this fundamentally erroneous idea the fact that no modal progress could be constructed upon a basis of closure tendency and also the fact that no thought of the problem of lapsed union entered the mind of previous workers and all the elements for complete confusion confront the investigator. Thus our predecessors found themselves entirely at the mercy of a meaningless closure average which must vary with every collection of crania.

From the foregoing statements it is apparent that no effective use can be made of the facts culled and deductions drawn by earlier workers. We should only confuse the reader were we to present and discuss individually the observations which others have made. Should reference to these be desired it can be readily obtained by studying the writings of Frédéric, Ribbe and Pommerol. We shall make only infrequent allusions to these earlier efforts in succeeding pages.

In 1895 Pearson, discussing the value of the mortality curve in enabling one to localize the time and manner of selection, points out the difficulty in separating the effects of growth from those of selection upon the basis of our present knowledge (14). It is precisely this same difficulty which we are attempting to reduce by ascertaining what exactly are the effects of growth and of differentiation in the normal body. Only when this is done shall we be in a position to discuss selection adequately. Hence the fundamental importance of investigating the most readily obtainable part of the body, namely the skeleton, from the standpoint of age. Pearson further points out the salient fact that, with few exceptions, Man is the only form of life whose age at death is known. But as I have shown for the symphysis pubis, as Graves has indicated for the scapula and as Stevenson has demonstrated for epiphyseal union, there is another standard by which we may gauge comparable ages throughout the mammalian class including Man. This does not involve years of life but depends upon comparable progress in skeletal growth and differentiation. With this discriminative balance ready to hand, a balance constantly becoming more delicate as we ac-

cumulate the necessary facts, biologists and anthropologists will find themselves enabled to weigh evolutionary problems which hitherto have defied all attempts at solution. The question of the cranial sutures is one of the most important pieces of evidence which can be thrown into this biological balance.

The striking feature of closure in the lambdoid suture is the long delay in the final stages of union (Fig. 4). Something of the same character appears in both the sagittal and the coronal sutures, more in the latter than in the former, but the delay in these is nothing like so great as in the lambdoid. Once again the upper two parts run a parallel course as in the coronal suture. The third or pars asterica, though following the others closely until thirty years, maintains a rather independent course thereafter. The distinction is not so marked as in the coronal suture but this is largely due to the curious terminal delay in the partes lambdica and media.

The actual facts regarding closure of the lambdic and medial segments may be thus summarized:—

Male White endocranial lambdoid closure commences at twenty-six years with

- (a) a sharply maintained rise to 3.4 at thirty-one, after which it
- (b) progresses slowly and irregularly to
- (c) complete union at forty-two years.

Age	Period	Number of skulls	
		Retained	Rejected
18-25	pre-(a)	15	2
26-30	(a)	16	6
31-41	(b)	72	15
42-84	(c)	164	17

Percentage of discards (a)—(b) inclusive on total of these periods..... 19.3

The analytic curves (Fig. 4) show a remarkable regularity of general progress on both sides and in both parts. Commencement of closure occurs in both pars lambdoidea and pars media at twenty-six and final closure takes place uniformly at forty-two. The curious terminal delay cannot be explained at this stage of the presentation. Its elucidation will be clarified in our later work. The course of the curve is not due to a distribution of wholly patent and completely united sutures; there is tremendous variability in the extent of union in different crania during the period (b). In this respect the pars media compares well with the pars lambdoidea; it does not actually precede the lambdoidea in its progress as maintained by some previous workers.

ENDOCRANIAL CLOSURE OF THE PARS ASTERICA OF THE LAMBDOID SUTURE

As in the coronal suture we have segregated the third segment, namely the pars asterica of the lambdoid which also shows a considerable delay in progress of union compared with the rest of the suture. In brief the facts may be stated as follows:—

Male White endocranial lambdoid closure (pars asterica alone) commences at twenty-six years with

- (a) an increasingly steep and fairly steady rise to 2.2 at thirty, when
- (b) the curve progresses more slowly and much more erratically to
- (c) complete closure at forty-seven years.

Age	Period	Number of skulls	
		Retained	Rejected
18-25	pre-(a)	15	2
26-29	(a)	10	5
30-46	(b)	109	22
47-84	(c)	133	11
Percentage of discards (a + b) on total of these periods 18.5			

THE DISCARDS OF THE SECOND HALF OF THE LIFE SPAN

The thirteen crania up to and including the age of thirty-seven years showing an abmodal progress of suture closure have already received attention. There are still twenty-seven crania of thirty-eight years and over which do not fit in with the modal course of suture union. It is convenient to consider these together and they are therefore gathered together at the end of this section. The irregularities shown are very diverse in nature. Sometimes only a segment or two of a single suture present anomalies of closure. Sometimes the irregularity is more widely spread. In certain crania the sagittal and lambdoid sutures are at fault, sometimes the coronal and lambdoid. No crania have been withheld solely on account of lapsed union although there are such specimens in this group of abmodal crania. Instances of lapsed union are marked with an asterisk (*). A few crania showed only a slight and localized abmodality and in each this was weighed very carefully before the skull was dismissed from the typical series. In every instance it was felt that, however slight the anomaly might seem to be, accuracy required that for the present at least the cranium should be eliminated.

The formulae show that delayed union is the main cause of rejection and this delay is more marked in the lambdoid suture than in the other two. This is quite in accordance with the fact that union in the lambdoid is normally later than in the sagittal and coronal. We shall see further

ENDOCRANIAL SUTURE CLOSURE

on that extravagant lethargy in closure of the lambdoid is even more marked in the Negro series and results in the rejection of a much greater proportion of Negro skulls. I am convinced that much of the confusion in previous examinations of suture closure has been caused by the irregularity of lambdoid closure the explanation of which cannot be attempted at this stage.

Age 38.	No. 480.	Sagittal 4444;	Coronal	R. 333	; Lambdoid	R. 334
				L. 444		L. 333
				R. 000		R. 420
	No. 581.	Sagittal 4444;	Coronal		; Lambdoid	
				L. 000		L. 110
				R. 000		R. 000
	No. 801.	Sagittal 0242;	Coronal		; Lambdoid	
				L. 000		L. 000
				R. 044		R. 310
Age 39.	No. 550.	Sagittal 2244;	Coronal		; Lambdoid	
				L. 020		L. 110
				R. 430		R. 000
	No. 892.	Sagittal 4143;	Coronal		; Lambdoid	
				L. 440		L. 000
				R. 243		R. 000
Age 40.	No. 351.	Sagittal 0010;	Coronal		; Lambdoid	
				L. 243		L. 000
				R. 010		R. 000
	No. 619.	Sagittal 0140;	Coronal		; Lambdoid	
				L. 020		L. 000
				R. 444		R. 000
	No. 740.	Sagittal 4444;	Coronal		; Lambdoid	
				L. 444		L. 000
				R. 343		R. 444
	No. 772.	Sagittal 4444;	Coronal		; Lambdoid	
				L. 343		L. 444
				R. 444		R. 330
	No. 952.	Sagittal 4444;	Coronal		; Lambdoid	
				L. 344		L. 320
				R. 000		R. 010
Age 44.	No. 819.	Sagittal 4334;	Coronal		; Lambdoid	
				L. 000		L. 000
				R. 444		R. 400
Age 45.	No. 320.	Sagittal 43*43*;	Coronal		; Lambdoid	
				L. 444		L. 400
				R. 444		R. 030
	No. 395.	Sagittal 43*44;	Coronal		; Lambdoid	
				L. 444		L. 020
				R. 000		R. 3*42
	No. 689.	Sagittal 42*44;	Coronal		; Lambdoid	
				L. 033		L. 440

			R. 444		R. 000
Age 46.	No. 188.	Sagittal 4444;	Coronal	; Lambdoid	
			L. 444		L. 000
			R. 343		R. 0*43
	No. 352.	Sagittal 0444;	Coronal	; Lambdoid	
			L. 444		L. 0*43
Age 47.	No. 701.	Sagittal 3100;	Coronal	; Lambdoid	
			R. 034		R. 440
			L. 044		L. 431
Age 48.	No. 213.	Sagittal 3100;	Coronal	; Lambdoid	
			R. 000		R. 233
			L. 100		L. 230
	No. 332.	Sagittal 4444;	Coronal	; Lambdoid	
			R. 444		R. 200
			L. 444		L. 000
Age 50.	No. 183.	Sagittal 0342;	Coronal	; Lambdoid	
			R. 000		R. 000
			L. 000		L. 000
	No. 758.	Sagittal 0000;	Coronal	; Lambdoid	
			R. 040		R. 000
			L. 000		L. 000
	No. 768.	Sagittal 43*44;	Coronal	; Lambdoid	
			R. 110		R. 100
			L. 110		L. 110
Age 51.	No. 96.	Sagittal 0444;	Coronal	; Lambdoid	
			R. 44?		R. 440
			L. 00?		L. 443
Age 52.	No. 890.	Sagittal 4444;	Coronal	; Lambdoid	
			R. 320		R. 2*20
			L. 320		L. 1*30
Age 53.	No. 325.	Sagittal 4444;	Coronal	; Lambdoid	
			R. 443		R. 3*40
			L. 440		L. 0*00
Age 55.	No. 384.	Sagittal 4443*;	Coronal	; Lambdoid	
			R. 443		R. 3*40
			L. 443		L. 3*00
Age 56.	No. 393.	Sagittal 4444;	Coronal	; Lambdoid	
			R. 3*40		R. 420
			L. 3*40		L. 240

GENERAL OBSERVATIONS UPON CLOSURE OF THE VAULT SUTURES

In the foregoing pages we have learned the method of scrutinizing our material and the details of closure progress for each part of the three sutures of the vault. We have now to observe that upon these data there begins to take form an altogether new conception of what suture closure progress implies, a conception which permits a comparison at

once with other races and with other mammals and brings into their true perspective very important phenomena of suture union.

The general graphs (Fig. 1) indicate that for White males union as a rule begins in the order, sagittal, coronal and lambdoid. They show that the progress in closure occurs in the same order and that the curves of progress of these successive sutures never actually cross each other. Whereas union commences in the sagittal at twenty-three (twenty-two for the obelica) its beginning is delayed in the coronal until twenty-four and in the lambdoid until twenty-six. This is a fairly rapid succession compared with the ages of completed union for in the sagittal closure is perfected at thirty-five but in the coronal not until forty-one and in the lambdoid it does not occur until forty-seven years. A curious fact, and as we shall presently see, a very significant one, is that there is a period of great activity in union progress during the latter half of the third decade. The great slowing up of closure only occurs after this when the sutures are already three-quarters united.

We now turn to the analytic graphs (Figs 2, 3, 4). The third part of each suture (obelica, pterica, asterica) has a progress more or less independent of that of the remainder of the suture. The obelica has a very short period of initial delay and then climbs steadily to complete union without any terminal prolongation. The age at which union is complete, namely twenty-nine years, is the beginning of a quite significant period in the history of the cranium and of the skeleton in general. The pterica and to a less extent the asterica, though commencing to close with or soon after the remainder of the coronal and lambdoid sutures respectively and continuing with them until twenty-nine or thirty years, exhibit thereafter obvious lagging, the precise significance of which cannot at the moment be explained.

The remaining parts of each suture, at whatever age they may commence to unite, present an initial period of laggard progress but at twenty-six or twenty-seven years the curves of all shoot up steadily and reach a varying degree of union by the age of thirty years or thereabouts when slowing up of the progress again makes itself evident. One must class these sutural elements together and differentiate them from the segments already discussed. The true sutures of the vault are not the sagittal, coronal and lambdoid in their entirety but these three sutures with the pterica and asterica omitted. The obelica is a law to itself and the pars verticis in its slowing up at twenty-nine, ahead of the other elements, shows unmistakably the influence of its neighbor the obelica.

The second fact which emerges at this juncture from our study is the definiteness of suture union as a feature of the age period between twenty-six and thirty years, that is to say the last stage of skeletal growth. This period, following immediately upon the completion of union of all epiphyses, is readily recognizable in all mammalian skeletons and its real significance becomes clear in our subsequent comparative studies.

It is very interesting, though we do not yet know how important, that by the age of twenty-nine the extent of closure in all these true sutural elements of the vault has reached a little more than three-quarters of their entire extent (about 3.4, see Figs 2, 3, 4). The slowing up of the pterica and asterica, which takes place at about the same age, finds these elements united to about half their entire extent (about 2.2). It is true that the sagittal progresses a fraction more by thirty-one. This is probably because the influence bringing about the slowing up does not act suddenly but arrests further activity between the ages of twenty-nine and thirty-one, namely the period at which the skeleton as a whole becomes stationary on reaching the completely adult condition. That there is some influence at work is certain for all the sutural elements, whatever their degree of union, show arrested activity at the same age. Is it not possible that we have here evidence of the final stage in general skeletal growth with the ultimate petering out of activity and the settling down of the skeleton into a quiescent adult condition at thirty years. If we may adopt this view, and subsequent presentation of our comparative studies will show how reasonable it is, then we have a criterion for judging of comparative values in suture closure. For the present we shall consider that the later years of the third decade in Man represent a definite period in the history of sutural closure.

THE CIRCUM-MEATAL SUTURES

(Fig. 5)

The next group of sutures is one centering upon the external auditory meatus. They are, in order from before backwards, sphenotemporal inferior and superior; squamous anterior and posterior; parieto-mastoid; masto-occipital superior, middle and inferior. Abutting upon this almost circular succession of sutures are the asterica of the lambdoid and, through the sphenoparietal, the pterica of the coronal.

Before considering these sutures in detail it is well to recall that there is a period of great activity in suture closure between the twenty-sixth and thirtieth years shown in all the sutures of the vault. What-

ever the time when union first begins in the vault sutures, closure progresses only slowly until twenty-six years, and after the acceleration between twenty-six and thirty closure progress again slows down quite independently of the degree of union attained by that date.

The speno-temporal and masto-occipital sutures, like the coronal and lambdoid, extend from the medial region of the cranium laterally, ultimately throwing themselves into the purely lateral squamous and parieto-mastoid sutures. These relations to the contour of the cranium will be found to be of the utmost significance.

No eliminations have been carried out on the basis of this group of sutures. In spite of the fact that Bolk found premature union far more common in the masto-occipital than in any other suture, namely 272 times in 1820 juvenile skulls, we have not discovered any such proportion. Bolk of course was dealing with the ectocranial sutures but even there we do not find a large proportion of premature union in the masto-occipital. So little being known concerning suture closure in this group and the actual progress illustrated by our preliminary graphs being so much less regular than in the vault sutures we have felt it advisable to carry out our eliminations upon a basis of the vault sutures alone. As a matter of fact a study of the discards shows in two only of the forty abnormal crania a real difference between the character of the masto-occipital sutures and that of the vault sutures. No. 653, of age twenty-six, exhibits a retarded condition of the vault sutures but an erratically accelerated union in the masto-occipital sutures. No. 242, of age thirty-five, presents a retarded condition of the vault and an erratically retarded appearance of the masto-occipital. The other discards show no anomaly of the circum-meatal sutures. We have however rejected them from all final graphs upon the basis of their vault sutures so as to obtain a consistent series.

The swinging course of the closure curves in these circummeatal sutures is undoubtedly due to the relative paucity of material for certain ages. With a much larger series, even with the addition of the forty rejects, the curves would have been more regular in their course.

THE MASTO-OCCIPITAL SUTURE

(Fig. 5.)

The masto-occipital suture finds a more or less natural subdivision into three parts and this subdivision we have followed. It is apparent however that, as in the case of the coronal and lambdoid sutures, the first and second parts cannot well be separated in their closure whereas

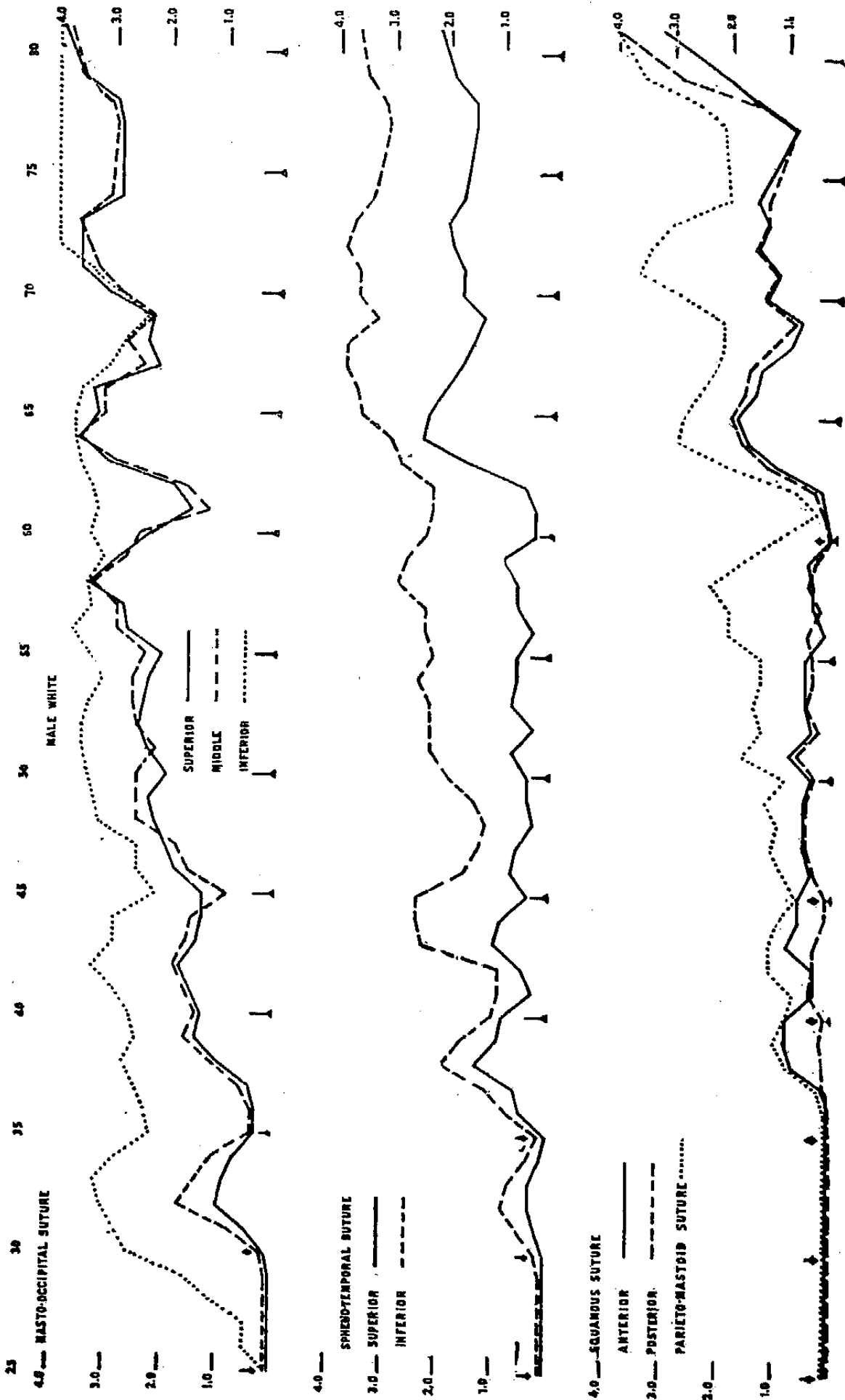


FIG. 5. Endocranial closure progress in the circum-meatal sutures. The progress in all these except the third (inferior) part of the masto-occipital suture is obviously different from the closure pattern of the vault sutures.

the third or pars inferior falls into a category by itself (Fig. 5). In our presentation of the facts we shall therefore treat the third part separately from the other two.

SUPERIOR AND MIDDLE PARTS

Closure commences in the superior and middle parts of the suture at thirty years and by thirty-two has reached an average of 1.25. At this level the curve remains fairly steady, barring oscillations, until forty-six. At this age slow progress is again made and continues until sixty-four when a second period of relative inactivity begins at about 3.5, studded with oscillatory movements of the curve, and is terminated by the climbing of the curve to 4.0 at eighty-one years. The peculiarity of this curve of closure brings to mind certain facts already ascertained in the study of other sutures. The appearance of the retarding influence at thirty-two is to be expected. Between forty-two and forty-seven years union is completed in the lambdoid suture which is of course neighbor to the masto-occipital. After sixty-four the inactivity which we find to be characteristic of other circum-meatal sutures is apparent here also. And again the final burst of energy at eighty-one is evident. I do not desire to make too much of these similarities at this point in the discussion but wish to draw the reader's attention to them in passing.

The facts regarding closure of the partes superior and media may be stated in the following manner:—

Male White endocranial masto-occipital closure commences at thirty years with

- (a) a short period of activity resulting in a rise to about 1.25 at thirty-two, when the condition becomes practically stationary until forty-five.
- (b) from forty-six until sixty-four there is a period of renewed activity, the curve rising erratically to 3.5, after which
- (c) a second period of relative quiescence supervenes, broken by
- (d) a final burst of activity at eighty-one years.

Age	Period	Number of skulls	
		Retained	Rejected
18-29	pre-(a)	25	7
30-45	(a)	106	20
46-63	(b)	94	13
64-80	(c)	39	0
81-84	(d)	3	0

Percentage of discards (a)—(c) inclusive in total of this period 13.8

THE MASTO-OCCIPITAL SUTURE (PARS INFERIOR)

Closure of the inferior part of the masto-occipital suture commences at twenty-six, four years earlier than in the remainder of the suture but at the same age as in the lambdoid. It progresses rapidly until thirty when it begins to slow down. Having reached 3.2 at thirty-three the curve remains at this level until forty-eight. After this age the curve oscillates round 3.5 until seventy-two years when complete closure is attained. There is really no great difference in this record from that of the superior and middle parts of the suture where thirty-two and forty-six years are significant dates. The final completion of union however occurs a decade earlier.

The ensuing table gives the facts briefly.

Male White endocranial masto-occipital (inferior) closure commences at twenty-six and

- (a) gathers speed rapidly until thirty years when
- (b) the curve of union becomes retarded about the point 3.2 until forty-nine when
- (c) a period of slow progress sets in anew, resulting in a rise to 3.5, continuing at this level until seventy-two, when
- (d) a final spurt of activity carries it to complete union.

Age	Period	Number of skulls	
		Retained	Rejected
18-25	pre-(a)	15	2
26-29	(a)	10	5
30-48	(b)	120	25
49-71	(c)	109	8
72-84	(b)	13	0
Percentage of discards (a)-(c) inclusive on total of this period.....			13.4

The most striking feature of union progress in the masto-occipital suture is the attempt of the third part to follow the type illustrated by the vault sutures. There is the same accelerated progress between twenty-six and thirty years and the same slowing down about that date. The upper parts of the coronal and lambdoid have reached the point 3.4 when stagnation sets in; the inferior masto-occipital has attained 3.2 when slowing takes place.

The superior and middle parts have barely commenced to close when they begin to feel the effect of the retarding influence so strongly marked in the other sutures already discussed. This influence is inhibitory but not prohibitory for union continues to progress but much more slowly. It is the almost imperceptible progress after the inhibitory influence has become effective that will, before long, be found to be the characteristic

of closure in sutures which have broken away in their time relationship from the typical mammalian form. Later on we shall be able to discuss this curious phenomenon in greater detail. It occurs in each suture of the circum-meatal group.

The final stage of closure of the inferior masto-occipital suture is very long drawn out, and that it is certainly completed at seventy-two and not earlier would be difficult to assert. Later we shall see that there is a close parallel between the final stage in this suture and the final stage of closure in the sphe-no-frontal which however terminates at sixty-four. The difference in time between the actual dates of complete union in these two sutures must not be allowed to obscure the very close harmony apparent in the general course of their closure curves.

THE SPHENO-TEMPORAL SUTURE

(Fig. 5.)

There is a distinct advantage in subdividing the sphe-no-temporal suture into superior and inferior parts for our investigation shows that the restraining influence affects in different degree the closure of the two parts (Fig. 5).

THE INFERIOR PART

Closure in the inferior part first makes its appearance at thirty years and, showing clearly the effect of inhibition, progresses very slowly until sixty-seven when the maximum union of 3.9 is attained. For practical purposes the suture is now completely united. The period between thirty and sixty-seven is naturally marked by oscillations of the curve but with a very much larger series one would be justified in expecting these oscillations to rule themselves out. The fact that closure is never quite complete is fully in harmony with the remarkably slow progress of union in this suture.

Age	Period	Number of skulls	
		Retained	Rejected
18-29	pre-(a)	25	7
30-66	(a)	205	33
67-84	(b)	37	0
Percentage of discards (a) on total of this period			12.0

SUPERIOR PART

Closure in the superior part of the sphe-no-temporal suture makes its earliest appearance at thirty-one, practically the same age as beginning closure in the inferior portion. But unlike the process in the latter segment progress is more definitely restrained and no further closure

takes place until the age of sixty-three when there is a sudden burst of energy which carries union up to 2.4, its maximum, at sixty-four. Beyond this age there are oscillations as there are between thirty-one and sixty-two but on the whole no further progress is made. As in other sutures it is impossible to avoid the impression that some delaying influence begins to be felt at about the age of thirty.

Age	Period	Number of skulls	
		Retained	Rejected
18-30	pre-(a)	31	8
31-62	(a)	187	32
63	(s)	7	0
64-84	(c)	42	0

Percentage of discards (a+b) on total of this period 11.9

We have already seen that the third part of the masto-occipital suture reproduces in the main the features of closure exhibited in the upper parts of the coronal and lambdoid sutures, whereas the superior and middle parts of the masto-occipital suture present a new type of closure progress. We now observe that the inferior part of the speno-temporal suture reproduces the features of closure progress seen in the upper part of the masto-occipital. The superior speno-temporal on the other hand shows a further deviation from the type common to all the vault sutures. There is practically no union at all until comparatively late in life. It is not until sixty-three years that closure becomes well marked and it is noteworthy that this age is one at which there is generally a spurt of activity recognizable clearly in other sutures also.

THE SQUAMOUS SUTURE

(Fig. 5.)

As a precautionary measure we have subdivided the squamous suture into anterior and posterior parts as was done by previous workers but our examination demonstrates that there is no real advantage to be gained from this arrangement. A glance at the graph (Fig. 5) illustrates this quite clearly. Consequently we shall not regard the subdivision except in the final analysis.

A slight degree of closure appears in (the posterior part first of) this suture at thirty-seven years but, apart from oscillations, never progresses beyond 0.5 until sixty-two when there is a renewed activity and the curve of closure rises sharply to about 1.75. There now follows a second period of stagnation until seventy-nine years when activity again appears and the maximum union is attained at eighty-one. This maximum is 4.0 or complete closure for the posterior part but only 3.2 for the anterior.

In the analysis one finds that closure begins in the anterior part on both sides at thirty-eight and is never complete. In the posterior part it commences on both sides at thirty-seven, terminating in complete union beyond eighty-one if ever.

Age	Period	Number of skulls	
		Retained	Rejected
18-36	pre-(a)	67	12
37-61	(a)	150	28
62-64	(b)	11	0
65-78	(c)	35	0
79-80	(d)	1	0
81-84	(e)	3	0
Percentages of discards (a)-(d) inclusive on total of this period, 12.3			

THE PARIETO-MASTOID SUTURE
(Fig. 5)

Closure in the parieto-mastoid suture follows very closely the progress of union in the squamous suture of which it may almost be considered a continuation (Fig. 5).

The first appearance of union occurs at thirty-seven years though little progress is made until the age of fifty-one. After this the curve shows greater oscillations but on the whole is somewhat speeded up in rate and complete union is attained at eighty-one as in the posterior squamous. It is possible, though our records do not definitely show it, that this suture participates in the increased activity apparent in the squamous at about sixty-two. But since the records are equivocal upon this point it is at least impossible to assert that closure steadily progresses as in the inferior sphenotemporal suture.

Age	Period	Number of skulls	
		Retained	Rejected
18-36	pre-(a)	67	12
37-80	(a)	197	28
81-84	(b)	3	0
Percentage of discards (a) on total of this period, 12.3			

GENERAL REVIEW OF CIRCUM-MEATAL CLOSURE

It is now possible to make a general survey of the features of closure progress in the circum-meatal group. It differs in all more or less markedly from the type pattern of progress as exhibited by the vault sutures. We shall refer to this condition as emancipation in various degree.

Of the several sutures the squamous exhibits emancipation in highest degree. In it there is no closure at all worth consideration until sixty-

three years when the curve runs up sharply to about 1.75. After this burst there is no further activity in the anterior part until the later spurt commencing about seventy-nine which carries the curve to 3.2 by eighty-one years. In the posterior part emancipation is not so well maintained for the last period of activity in old age brings the curve up to 4.0, namely complete union.

The parieto-mastoid suture, though following fairly closely the closure pattern of the squamous, presents features intermediate between those of the superior and inferior speno-temporal sutures, resembling indeed the former more than the latter. As in the case of the squamous the initial start is delayed till the end of the fourth decade but more progress is made after fifty-one years. From this time on a slightly increased rate is maintained which ultimately results in complete union. Hence in later life the progress of the parieto-mastoid suture is more like that of the inferior speno-temporal suture. In middle life its closure pattern resembles that of the superior speno-temporal and the squamous.

The superior speno-temporal suture gets a rather earlier start than the squamous though it is doubtful if this should receive much weight since it is so badly maintained. Once it has started the features of the curve are very like those of the squamous and it participates in the renewed activity of the earlier years of the seventh decade.

The inferior speno-temporal and the superior and middle parts of the masto-occipital run almost parallel courses which have been sufficiently indicated. The inferior masto-occipital shows the least degree of emancipation from the type pattern of the vault sutures.

Now, if the curves for the pterica of the coronal, the asterica of the lambdoid and the inferior masto-occipital be compared it will be seen that they form a graded sequence in emancipation from the true vault suture closure pattern. We may then establish a sequence in emancipation showing the lowest grade in the coronal pterica and the highest in the anterior squamous. The order of emancipation is the following:—

Coronal pterica; lambdoid asterica; inferior masto-occipital; superior and middle masto-occipital and inferior speno-temporal; parieto-mastoid; superior speno-temporal; posterior squamous; anterior squamous.

SIGNIFICANCE OF THE DISCARDS

It has already been stated that the discards have been rejected upon the basis of their vault suture progress alone. That there should be but two crania which could be fairly discarded upon the basis of progress in

union of the circum-meatal sutures is an arresting fact and, taken in conjunction with the results of our observations upon the vault, a problem worthy of further study. I have mentioned that, in all sutures the retardation of closure progress commencing about the age of thirty years is an inhibition rather than a prohibition of further closure. There are however certain crania in which further union seems to be permanently inhibited. To this we must return later but its occasional occurrence is a natural extreme degree of the variability induced by the retarding influence.

TABLE I. TABLE OF DISCARDS—MALE WHITE

1 Age period (Decade)	2 Total	3 Discards		5 Remaining in series		7 Percentage of discards		
		Inclusive of all (A)	Retarded only (B)	Total —col. 3 (A)	Total —col. 4 (B)	Col. 3 to col. 2	Col. 4 to col. 2	Col. 4 to col. 6
10-19 (2nd)	2	0	0	2	2			
20-29 (3rd)	30	7	4	23	26	23.3	13.3	15.4
30-39 (4th)	67	11	9	56	58	16.3	13.4	15.5
40-49 (5th)	81	14	10	67	71	17.3	12.3	14.1
50-59 (6th)	61	8	7	53	54	14.7	11.5	13.0
60-69 (7th)	44	0	0	44	44			
70-79 (8th)	19	0	0	19	19			
80-89 (9th)	3	0	0	3	3			
Totals	307	40	30	267	277	13.3	9.8	10.8

If we refer to the table of discards (Table I) we observe that there is no plain relation between the number of discards and successive age periods (column 7). But if the crania showing accelerated, locally anomalous and erratic closure be discounted, leaving only those discards which exhibit pure retardation, then we find a very significant relationship of discards both to the total number of each age period (column 8) and to the number of modal crania left in each age period (column 9). The discards are all eliminated upon the basis of their vault sutures and the vault sutures all attain complete union during the fourth and fifth decades. During the third and fourth decades the percentage of discards remains stationary but diminishes in the fifth and sixth decades and there are no retarded examples found beyond the latter. We do not here propose to discuss permanently inhibited suture union which we term for convenience the asterisked suture; we refer only to pure retardation.

We have seen by the graphs that retardation setting in about thirty years is merely a slowing down influence and does not result in any permanent prohibition of union. We now see from this table that the

discards, eliminated because of retardation in vault closure, exhibit merely delayed union and that eventually their vault sutures would probably all close. We are then observing the effect of an influence which tends to make its presence felt throughout adult life in Man, affects some sutures (the circum-meatal group) more than others (the vault group), and has a specially marked effect appearing quite suddenly at about thirty years. Granting that we are compelled by the facts to concede the existence of a retarding influence, we may expect that certain sutures will exhibit retardation more than others. This has already been demonstrated (page 370). Concerning the cause for the existence of the retarding influence it is rather early in the discussion to build any hypothesis but I consider the retarding influence related to local evolutionary development of the cerebrum.

Turning now to the several lists of discards it becomes evident that retardation is much more marked in the lambdoid than in either of the other vault sutures. As a rule also it is the lower part of the suture which shows retardation most clearly. This means of course that in certain crania the lambdoid suture presents a closure progress resembling more or less closely that of the circum-meatal group. We note this tendency even in the modal course of the lambdoid graphs (Fig. 4). It is by no means to be inferred that the sequence of emancipation in the circum-meatal group is rigidly adhered to, or that I desire to emphasize the several degrees of emancipation. Rather I would explain that there are groupings of sutures which present closure patterns intermediate between the extreme types illustrated by the true vault sutures on the one hand and the squamous on the other. If we start with the squamous itself and follow the suture line backward we are able to note progressively less degrees of emancipation as we trace the parieto-mastoid and then either the lambdoid upward to the lambda or the masto-occipital downward, which latter sutures may be considered as the inverted mirror image each of the other.

It is probably this varying emancipation of the lambdoid suture which has produced confusion in the statements of previous authors regarding early or late closure of the lambdoid suture compared with union of the coronal. It is probably also responsible for the fairly wide-spread belief that there is some relation between the relative date of lambdoid closure and the cephalic index.

THE ACCESSORY SUTURES

(Fig. 6.)

We now pass to the consideration of two sutures which in view of their position, scarcely belong to the circum-meatal group, and more cer-

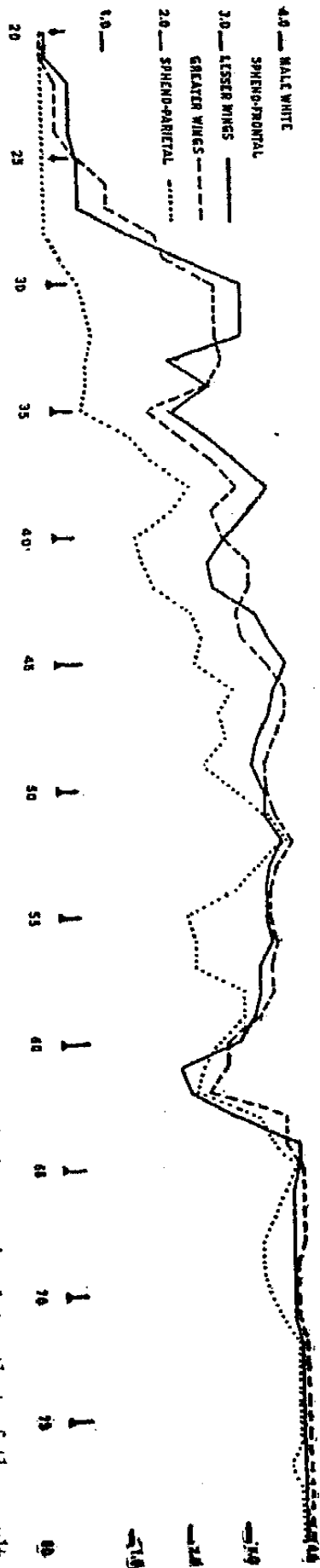


Fig. 6. Endocranial closure progress in the accessory sutures. The pattern of sphenofrontal closure simulates that of the vault sutures whereas that of sphenoparietal closure resembles more closely the pattern of circum-meatal closure.

tainly, by their closure pattern, form no part of the vault series. These are the speno-parietal and speno-frontal sutures. As the story of their closure is unravelled it becomes clear that they lie upon the threshold of emancipation and form, as it were, a link between the true vault sutures and the circum-meatal group.

THE SPHENO-PARIETAL SUTURE

(Fig. 6.)

Closure in this suture commences at twenty-nine and, encountering the delaying influence almost at once, progresses quite gradually and with many oscillations until forty-six when the graph has reached the level of 3.0. After this the course of the graph (Fig. 6), is very irregular although there is some slight progress until sixty-four. At sixty-five complete closure is attained as in the speno-frontal suture. It is true that the graph shows a sagging of the curve beyond this point but I am inclined to regard this as spurious and simply resulting from paucity of material.

The facts briefly are these:—

Closure commences at twenty-nine years and is almost immediately slowed down so that there is a

- (a) slow progress to forty-six when the curve stands at 3.0, then
- (b) a period of considerable oscillation with little progress to sixty-four,
- (c) complete union occurring at sixty-five.

Age	Period	Number of skulls	
		Retained	Rejected
18-28	pre-(a)	23	6
29-45	(a)	108	21
46-64	(b)	97	13
65-84	(c)	39	0
Percentage of discards (a+b) to total of this period			14.2

The type of closure of this suture corresponds very closely with those exhibited by the inferior speno-temporal and by the superior and middle parts of the masto-occipital. This is the more striking since closure of the speno-frontal and of the inferior part of the masto-occipital is found to be so harmonious. Closure in the speno-parietal begins indeed one year earlier than in the upper masto-occipital but in both there are distinct periods between thirty and forty-five, and from forty-six to sixty-four. Both periods are characterized by slow progress, it may be very slow, and the completion of union in the speno-parietal is balanced by the attainment of the maximum closure in the masto-occipital.

We see therefore lesser stages of emancipation in the several sutures progressively more remote from the focus of emancipation, namely the anterior squamous.

THE SPHENO-FRONTAL SUTURE

(Fig. 6.)

In considering the sphe-no-frontal suture one cannot help the suggestion that here we have a suture which, like the sagittal and the inferior masto-occipital has only a remote and modified relation to phenomena of cerebral development. One is therefore already prepared to find a graph of the moving average different from those of the other sutures which carry its line backwards.

In the first place the graph (Fig. 6), shows a close parallel between the curves of the two parts so that it becomes unnecessary to treat them separately.

In both parts closure commences at twenty-two and, as usual, makes rather slow progress during the next years. In the region of the greater wings at twenty-five and in that of the lesser wings at twenty-seven the rate of union rapidly increases and by thirty years the curve centers at about 3.0. It is somewhat striking that the speeding up process begins for this suture, as for all the others, about the age of twenty-six. This speeding up is obviously a general characteristic of suture closure and un-related to particular location. After thirty years there is a long period of oscillation during which union on the whole makes no progress. This ends at sixty-four. At sixty-four the suture of the lesser wings, and at sixty-five that for the greater wings is completely closed.

These facts may be briefly stated in the following manner:—

Closure commences at twenty-two with

- (a) a gradual rise to 0.7 at twenty-six, followed by
- (b) a steeper progress to 3.0 at thirty, when there commences
- (c) a period of oscillation with no further union ending at sixty-four, and resulting in
- (d) complete closure at or about sixty-five.

Age	Period	Number of skulls	
		Retained	Rejected
18-21	pre-(a)	4	0
22-25	(a)	11	2
26-29	(b)	10	5
30-64	(c)	203	33
65-84	(d)	39	0

Percentage of discards (a)-(c) inclusive to total of this period..... 15.1

Comparison of the graphs of this suture and of the inferior masto-occipital shows a very striking likeness. It is true that closure commences about four years earlier in this suture than in the pars inferior of the masto-occipital but both exhibit the speeding up process about twenty-six, the slowing down at thirty years and the long ensuing period of oscillations without further progress. The similarity only breaks down in old age because of the unexpected, and probably unwarrantable, dip of the graph for the pars inferior in the sixties.

Comparison with the graph of the lambdoid asterica also shows striking similarities. Except for the early start of union in the spheno-frontal, a start which is not at all maintained, union follows an almost parallel course in both these sutures. Indeed the course of closure in the spheno-frontal may more properly be considered intermediate between those of the superior and middle lambdoid on the one hand and the pars asterica on the other. This similarity brings into one group the spheno-frontal, the lambdoid and the inferior masto-occipital, three sutures on the frontiers of the zone of emancipation, the center of which is in the anterior squamous. When one realizes this close similarity the early commencement of union in the spheno-frontal becomes all the more striking. For here on the very edge of emancipatory influence is a suture which begins to close as early as the sagittal, a suture undoubtedly presenting an ancestral stage in the time relationship of its commencing union. In further studies it will be our task to follow the clues given in age relationship of suture closure regarding the ancestral condition of the human closure pattern.

THE PERIODIC CHARACTER OF SUTURE UNION

In studies upon the skeleton, growth and differentiation should be sharply distinguished. The amount of increase in dimensions of a long bone is one thing and the actual union of its epiphyses is another. The two have been regarded as closely related aspects of a single problem. In certain cases of a pathological nature they are completely dissociated. I think it safer not to link them inseparably in normal anatomy until they have been definitely shown to justify this treatment. Actual increase in dimension may not be taking place uniformly throughout the period before actual epiphysical union though there may be, and probably are, continuous alterations in adjustment between epiphysis and diaphysis. This latter is a problem of differentiation, not of growth. Cranial suture closure has probably no very definite relation to cranial growth. Certainly the cranium is not growing in its various parts

throughout the life period until union of all the sutures takes place. Suture union is a problem of differentiation rather than of growth.

Having observed the picture of progressive closure as it presents itself in the several sutures we are now in a position to note that the nature of this progress differs greatly in different areas of the cranium. The course of closure in the vault sutures is not at all the same thing as the course in the squamous suture and between these two extremes there are intermediate types of progress related definitely to the particular area of the cranium in which the suture finds itself.

The age relationship in detailed progress of union varies with the suture but in all sutures there is a periodicity of union. We have observed marked activity of progress between the ages of twenty-six and thirty years and sudden diminution of activity immediately thereafter. No matter what stage of union is reached, the suture does not continue to unite so rapidly after thirty years as it did before. But although the period of extreme activity, one might say the typical period of suture union, occurs from twenty-six to thirty, there seem to be subsidiary periods when activity receives a further impetus, and these periods can be traced even into old age. In certain graphs it may indeed be doubted that any impetus can be discerned. Nevertheless in general the curves of union do show periodicity and spurts of increased progress tend to alternate with periods of relative quiescence. I have already demonstrated a similar periodicity in the differentiation (metamorphosis) of the pubic bone (19, 22) after adult life is reached, exhibiting a similar rather poorly defined age relationship. These are the periods of quiescence and secondary changes which are not as yet fully worked out for they do not present the clear cut age relationship characteristic of the earlier phases of pubic differentiation. It is as though Nature grew somewhat tired of regulating precisely the order and date of differentiation and gave more latitude to the individual after middle age. This relatively ill-defined age relationship is characteristic of all features of differentiation during the second half of the life span so far studied in this laboratory. It is only in later communications that I shall be able to lay stress upon this periodicity in differentiation to the extent which it deserves for I recognize that much more evidence from various parts of the skeleton must be presented before its existence and significance can be made clear.

In the present study it is however plain that cranial sutures tend to close with marked vigor between twenty-six and thirty years and there are varying degrees of emancipation from this regulation apparent

in certain sutures. The squamous suture shows emancipation in highest degree and the sutures in the vicinity of the squamous exhibit emancipation apparently depending upon the varying relation of their site to the squamous. The sphenofrontal and inferior masto-occipital sutures therefore present curves of closure progress most closely simulating those of the true vault sutures.

In order that the reader may clearly appreciate the complex age relationship and periodicity of suture closure I have drawn up a table giving briefly the outstanding facts (Table II).

TABLE II—CRANIAL SUTURES—MALE WHITE ENDOCRANIAL CLOSURE

Suture	Commencement and course	Termination (or peak)	
Sagittal.....	22	35	slows at 31 at 3.9
Sphenofrontal lesser w.....	22	64	slows at 30 at 3.0
Sphenofrontal greater w.....	22	65	final burst of activity slows at 30 at 3.0
Coronal 1 and 2.....	24	38	final burst of activity slows at 29 at 3.4
Coronal 3.....	26	41	slows at 29 at 2.1
Lambdoid 1 and 2.....	26	42	slows at 31 at 3.4
Lambdoid 3.....	26	47	slows at 30 at 2.2
Masto-occipital 3.....	26	72	32-48 at 3.2 slow progress thereafter
Sphenoparietal.....	29	65	29-46 at 3.0. slow progress thereafter
Sphenotemporal 2.....	30	67	at 3.9 gradual progress
Sphenotemporal 1.....	31	64	at 2.4 31-62 at 0.5
Masto-occipital 1 and 2.....	30	81	burst of activity at 63 32-45 at 1.25 activity between 46 and 64 final burst of activity
Parietomastoid.....	37	81	almost inactive till 50 slow progress thereafter
Squamous posterior.....	37	81	burst of activity at 63 burst of activity at 79
Squamous anterior.....	37	81	at 3.2 burst of activity at 63 burst of activity at 79

The sagittal and sphe-no-frontal sutures commence to unite at twenty-two years. There is slow progress until twenty-six when the period of rapid union sets in and lasts till about thirty years. By this time the sagittal is almost completely united and its terminal inhibition is of no real consequence. The sphe-no-frontal however is only three-quarters united at this age and falling under the restraining influence, its union remains practically stationary until the final burst of activity in the early sixties.

The upper part of the coronal suture, starting to unite two years later than the sagittal, follows a similar course but its terminal inhibition is not nearly so prolonged as that of the sphe-no-frontal for it is remote from the zone of maximum emancipation (squamous).

The pteric part of the coronal, the entire lambdoid and the third part of the masto-occipital all commence to unite at twenty-six and progress as far as thirty years is rapid. The pterica and asterica have united only about one-half their extent by thirty but the upper lambdoid and the third masto-occipital, being further removed from the zone of maximum emancipation, are three-quarters united. At thirty years retardation sets in and complete union attained at ages varying from forty-one to seventy-two.

APPLICABILITY TO INDIVIDUAL CASES

In a study of this kind it is natural for the reader to inquire what value it has for the identification of age in individual cases. Indeed when we first commenced the work we had in mind the utilization of suture closure, along with other features of skeletal differentiation, in estimation of the actual age of the person. In order to show what may be attained by the method I have taken thirty skulls at random and worked out the suture age for comparison with the known age. The results of this investigation are given in Table III. While the average computed age very closely approximates the average real age, as might be expected, the results in individual cases leave much to be desired for the average deviation is rather more than six years. I have not claimed greater accuracy than this for age estimation based upon any single segment of the skeleton and when one considers the individual variability in suture closure progress this result is far from discouraging. But it cannot be denied that so far our work does not justify the uncontrolled use of suture closure in estimation of age. Frédéric (7) concluded that it is not possible to gauge the age of any particular individual closer than within one decade and after all we have not greatly bettered this result.

Our results are of distinct value however when taken in conjunction with indications given by other parts of the skeleton.

The real value of this work lies in the light thrown by it upon the nature of suture closure. I have already dwelt upon this aspect of our results and it is only after presentation of our complete investigations,

TABLE III. ESTIMATION OF AGE BY ENDOCRANIAL CLOSURE

Skull	Suture age circa.	Actual age	Dev.	Skull	Suture age circa.	Actual age	Dev.
94	25	28	-3	618	30	30	
156	40	45	-5	649	27	22	+5
185	40	40		654	65	42	+23
267	25	25		671	35	33	+2
301	35	34	+1	678	40	38	+2
328	55	38	+17	708	45	32	+13
354	65	48	+17	711	43	47	-4
396	41	60	-19	772	37	40	-3
429	35	40	-5	786	43	45	-2
431	45	40	+5	794	33	32	+1
445	30	36	-6	799	35	36	-1
499	43	55	-12	823	30	33	-3
504	35	37	-2	828	58	68	-10
507	35	49	-14	876	43	ca 40	+3
617	37	32	+5	896	55	53	+2

Average of thirty. Suture age 40.2 years. Actual age 39.9 years. Dev. 6.2

which comprise Negro Stock and comparative mammalian anatomy, that we shall be able to demonstrate satisfactorily the full truth concerning suture closure. At the moment I can merely reiterate my belief, expressed in several places above, that there is a mammalian type of order and progress in suture closure from which various degrees of emancipation are exhibited in higher Primates. In Man the greatest degree of emancipation is attained. It is too early as yet to speculate upon the very interesting question whether the amount of individual variation should be construed as an indication of inadequacy in this emancipation, or whether the type of skull may have some real relation to the precise individual character of suture closure progress. Work along this line has been in prosecution for many months but so far I am not ready to report.

SUMMARY

The numbers of paragraphs in this summary refer to the numbers of corresponding subject headings in the table of contents.

1. So little work has hitherto been done upon endocranial suture

closure in material of definitely known age that it is necessary to make an absolutely fresh start. The previous work of Parsons and Box is the most helpful and suggestive.

2. The present survey included 307 male White skulls of age known either precisely or within a year or two. But since the making of the survey in 1921-22 we have had opportunity to test its principles upon a considerably increased collection and we find the principles are confirmed.

3. By a detailed preliminary survey we were able to identify a definite trend of progress in suture closure. There is obviously considerable individual variation but the mean values of the trend are closely similar in series restricted to one Sex and Stock. Abnormal examples must naturally be eliminated.

4. A three-yearly moving average or trend illustrates in a practical visual manner the progress of suture closure and its relation to age. It is unnecessary and indeed it would seem unwise, at least at the present stage, to smooth the graphs too much.

5. Endocranial closure progress compels us to adopt a new method of grouping the sutures. The group of vault sutures includes sagittal (and metopic), coronal and lambdoid with some reservations on the partes pterica and asterica of the two last. It does not include the squamous suture. A second group presenting an entirely different age-relationship in closure progress has been named by us the circum-meatal group. This includes the spheno-temporal, squamous, parieto-mastoid and occipito-mastoid sutures. The third and last group, styled the accessory group, comprises spheno-frontal and spheno-parietal sutures.

6. Frequently in the sagittal and lambdoid, rarely in other locations also, there occurs an apparent failure of union with heaped up bone tissue along the margins of the unclosed part. We have described it under the heading of lapsed union. This must be clearly distinguished from union which, though in fact incomplete, would normally have been completed later.

7. The elimination of specimens exhibiting what is known or suspected to be abnormal progress is an important step.

8. The sagittal suture commences to unite at twenty-two years and is practically completely closed at thirty-one, progress becoming much more rapid at twenty-six.

9. The coronal suture begins to close at twenty-four years. From twenty-six to twenty-nine there is rapid progress and thereafter union

spreads very slowly, completion being attained at thirty-eight. The pteric part is delayed in its commencement until twenty-six and in its completion until forty-one but it shows the same speeding up from twenty-six to twenty-nine.

10. The lambdoid suture begins to close at twenty-six and though progress is rapid until twenty-nine it is fitful thereafter until complete at forty-two. The asteric part, though commencing at the same age does not complete its union until forty-seven.

11. Crania presenting abnormality in suture closure are not infrequent. Sometimes the irregularity is localized to a single suture, or even to the segment of a suture. All such crania in this series have been rejected. The main cause of rejection is delayed union and this delay is more frequently met with in the lambdoid suture than in the sagittal or coronal.

12. Endocranial closure of vault sutures in male White crania commences and terminates in the order, sagittal, coronal, lambdoid. The discrepancy in age is greater for completion of union than for commencement. The age period of twenty-six to thirty years is the special period of suture closure. At whatever stage union may have progressed there is a significant slowing up once this period is passed.

13. The circum-meatal group of sutures presents a closure pattern quite different from that of the vault sutures. This group comprises the speno-temporal, squamous, parieto-mastoid and masto-occipital suture.

14. The masto-occipital suture commences to close just about the thirty-year period when lethargy in progress is setting in. A second period of activity is shown in the fifties and a third and final burst about eighty years. The inferior part however commences at twenty-six, slows down at thirty, gathers speed again in the fifties and finally reaches complete union in the seventies.

15. The inferior part of the speno-temporal suture shows a closure pattern similar to that of the major part of the masto-occipital but complete union is rare. The superior part is even more restrained in its degree of closure.

16. In the squamous suture closure does not begin until the late thirties and is rarely over complete, at least in the anterior part.

17. Closure in the parieto-mastoid suture presents a pattern similar to that of the squamous suture but complete union is attained as in the posterior squamous, at eighty or over.

18. The circum-meatal group clearly shows various degrees of emancipation from the closure pattern typified by the vault sutures. The

greatest degree of emancipation occurs in the anterior squamous suture.

19. The retarding influence which makes its appearance in suture closure at thirty years affects some sutures more than others but certain crania seem to exhibit retardation in more marked degree than others. In these sequence of union may remain unaffected.

20. The speno-parietal and speno-frontal sutures form a link, as it were, between the vault group and the circum-meatal group. We style them the accessory sutures.

21. In the speno-parietal suture closure, commencing at twenty-nine years, is almost immediately retarded but shows a second burst of activity in the fifties carrying union to completion in the early sixties.

22. Union in the speno-frontal suture begins at twenty-two, shows the usual activity from twenty-six to thirty years, after which oscillation and slow progress supervene until complete closure at about sixty-five.

23. Suture closure exhibits a definite periodicity, the most extreme activity occurring between twenty-six and thirty years. Subsidiary periods of activity occur in the fifties and the late seventies.

24. The individual variability in progress of suture union makes it unwise to depend too much upon the stage as an age marker, valuable as the indications may be when linked up with other features. The average progress of a large number of crania however shows that there is a definite pattern in suture union. The most primitive form is still represented in the sagittal suture and the greatest degree of emancipation from that primitive form is exhibited in the squamous suture.

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