ABSTRACTS.*

VERTEBRAL REGIONAL DETERMINATION IN YOUNG HUMAN EM-
BRYOS. By CHARLES RUSSELL BARDEEN. *University of Wisconsin.*

In 1904 I published a study of numerical vertebral variation in the
human adult and embryo (Anat. Anz., XXV. p. 498). In this article
I took exception to the views advanced by Rosenberg in 1876 (Morph.
Jahrb.) that in young human embryos the sacrum is composed of a
more distal set of vertebræ than it is in the adult, and that during
embryonic development there is a reduction in the number of thoracic
or rib-bearing vertebræ.

Rosenberg has recently (Morph. Jahrb., XXXVI, p. 609, 1907)
criticised my paper on two grounds:

1. That some of the data used in the statistical tables are incorrect,
inaccurate or without sufficient basis.

2. That the data used are incorrectly interpreted.

In support of the first criticism that data used in the table are
inaccurate or inadequate, Rosenberg goes into a careful study of the
embryos tabulated from his article of 1876 and of the embryos described
by Hagen and by Peterson. He finds only two of his embryos correctly
described by me and that the embryos of Hagen and Peterson are not
described by these authors with sufficient detail to merit their inclusion
in a statistical table.

Neither Rosenberg nor the other authors mentioned gave specific
detailed accounts of the vertebral columns of the embryos studied.
Rosenberg took up each of the regions of the vertebral column in
turn and used various embryos to illustrate each region. The data
concerning each embryo had to be gathered from the somewhat involved
account which he gave concerning the different regions of the spinal
column and from his figures. In deducing that Rosenberg's Embryo
V[1] had a "normal" vertebral column I undoubtedly, as Rosenberg
says in his recent article, had no sufficient data. The other inaccu-
racies which he attributes to me are due rather to interpretation from
a point of view different from that of Rosenberg than to a mistake
concerning the data which he furnished. It was, however, a mistake
to attribute 5 instead of 6 coccygeal vertebræ to Embryos IV[3] and III[1].

In utilizing the somewhat incomplete data of Hagen and Peterson I probably should have called more attention to the incompleteness of these data. Lack of better material led to their inclusion in the table.

The chief difference between the views maintained by Rosenberg and those which I have advanced comes from the interpretation which we give to embryonic data. Rosenberg would apply to embryos the ordinary criteria which are applied to the adult osseous skeleton in determining the cervico-thoracic, thoraco-lumbar, lumbo-sacral, and sacro-coccygeal boundaries, while to me it seems evident that the special features characteristic of the embryo must be taken into account. Rosenberg thinks that it is incorrect to call a vertebra a lumbar vertebra unless its cartilaginous or osseous costal element is intimately fused with the transverse process, and that it is incorrect to call a vertebra a sacral vertebra unless its cartilaginous or osseous costal element is intimately fused laterally into the lateral sacral plate. Thus, likewise, a vertebra is not a true cervical vertebra unless its costal element is intimately fused with the transverse process.

My studies of the development of the vertebral column have led me to the conclusion that there are separate centers of chondrification for the costal elements of each of the vertebra, from the first cervical to, and sometimes possibly including, the first coccygeal. In connection with the more distal coccygeal vertebra apparently no cartilaginous costal elements develop. I do not, however, agree with Rosenberg that progressive ontogenetic regional alteration is to be deduced from the independent origin of cartilaginous costal elements in connection with vertebræ to which these elements are firmly fused in the adult.

Let us take up briefly the development of the costal elements in the vertebræ in each of the regions of the spinal column.

1. *Cervical Region.*—The cervical region becomes distinct from the thoracic in the fifth week, at a period when centers of chondrification in the vertebræ are about to appear. The two regions are rendered distinct from one another by the rapid extension of the blastemal costal processes of the thoracic vertebræ into the thoracic wall (Fig. 1B). Th blastmal processes of the seventh cervical vertebra extend outwards further than those of the other cervical vertebræ, but there is less difference in length between the costal processes of the seventh cervical vertebra and those of the other cervical vertebræ than between those of the seventh cervical vertebra and those of the first thoracic. The great difference in length between the costal processes of the seventh
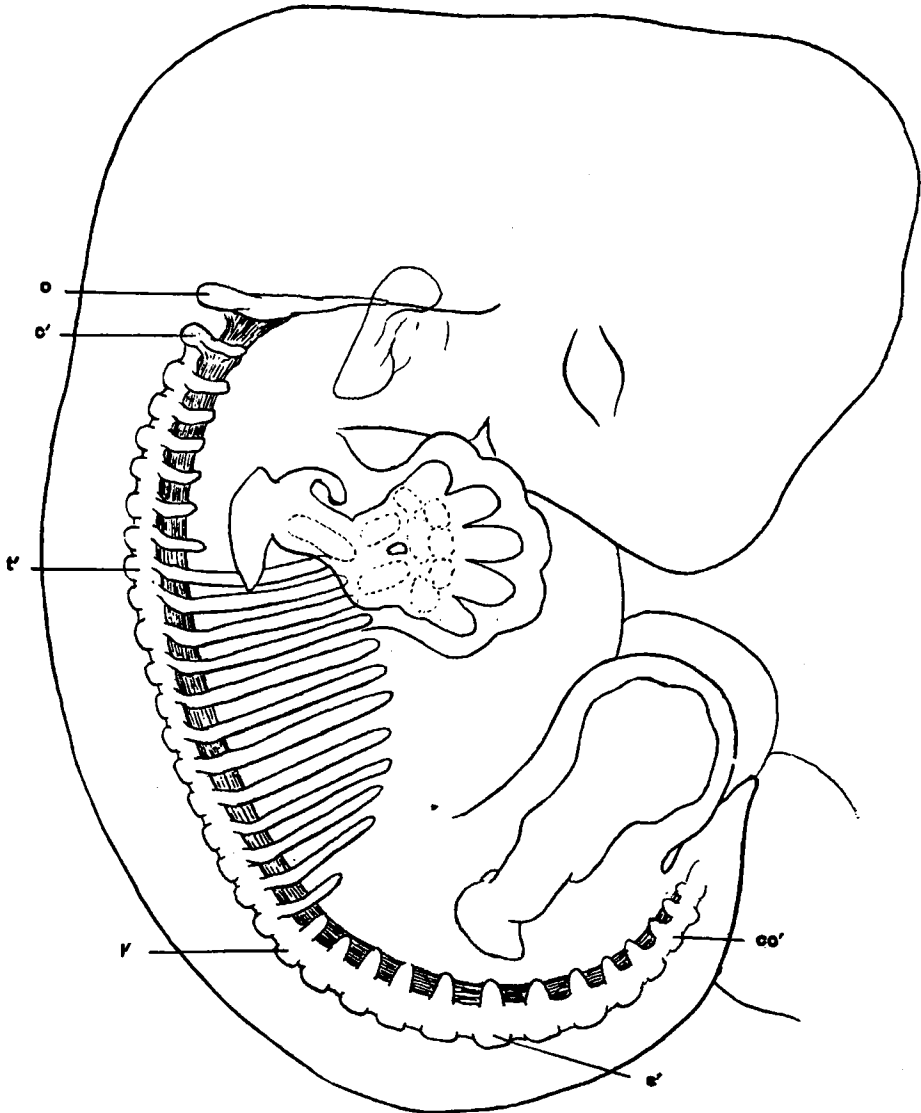
FIG. 1B.

Diagram of the skeleton of an embryo 11 mm. long and about five weeks old.

o, occipital plate.

c, first cervical vertebra.

t', first thoracic vertebra.

l', first lumbar vertebra.

s', first sacral vertebra.

co', first coccygeal vertebra.

cervical vertebra and those of the first thoracic is clearly indicated in the figures of Charlotte Müller. (Morph. Jahrb., 1906.)

In the costal process of the seventh cervical vertebra a center of chondrification is formed at the period when similar centers appear in the ribs. For this reason it may be correct to speak of the regular appearance of a pair of cartilaginous cervical ribs. I believe, however, that it would be more correct to speak of the costal elements of the seventh cervical vertebra as being more rib-like than those of the other cervical vertebræ rather than as true ribs. Normally they do not extend much beyond the transverse processes. The centers of chondrification for the costal elements of the other cervical vertebræ appear much later than those of the seventh cervical vertebra (usually not until the embryo has reached a length of from 16-18 mm.), and they fuse earlier with the transverse processes.

During the period of ossification, according to Leboucq, 1896, the ventral limb of the transverse process in most of the cervical vertebræ is ossified by ingrowth at one end from the pedicle, at the other from the tip of the transverse process. In the seventh cervical vertebra frequently, in the sixth occasionally, and in the fifth, second and fourth rarely, there arise during the second to the fifth months separate centers of ossification for the costal elements. According to Mall (Am. Journ. Anat., 1906), it is not certain that separate centers of ossification for the costal elements of the seventh cervical vertebra in the embryo are very much more frequent than cervical ribs in the adult. Undoubtedly cervical ribs are more common than one is led to believe from statistical studies of vertebral variation.

The presence of a more or less rib-like costal element in young human embryos would doubtless make it difficult or impossible to compare the relative frequency of "cervical ribs" in the adult and embryo. It would not be easy to determine how great a development of the costal element in the embryo would be necessary in order to make it comparable with a free cervical rib in the adult.

2. *Lumbar Region.*—This region becomes clearly marked off from the thoracic in the fifth week of embryonic development by the rapid growth which takes place at this time in the blastemal costal processes of the thoracic vertebræ. (See Fig. 1B.) This is shown not only in the embryos which I have studied, but also in those figured by Charlotte Müller, 1906. Slightly later it becomes distinguishable from the sacral region by fusion of the blastemal cartilaginous costal processes of the

latter to form a lateral sacral plate, the proximal part of which becomes united to the blastemal ilium (Bardeen, Am. Journ. Anat., 1905, Figs. 5 and 6). In the lumbar vertebræ it seems probable that there are separate centers of chondrification for each of the costal elements. These appear later than the centers for the ribs in the thoracic region
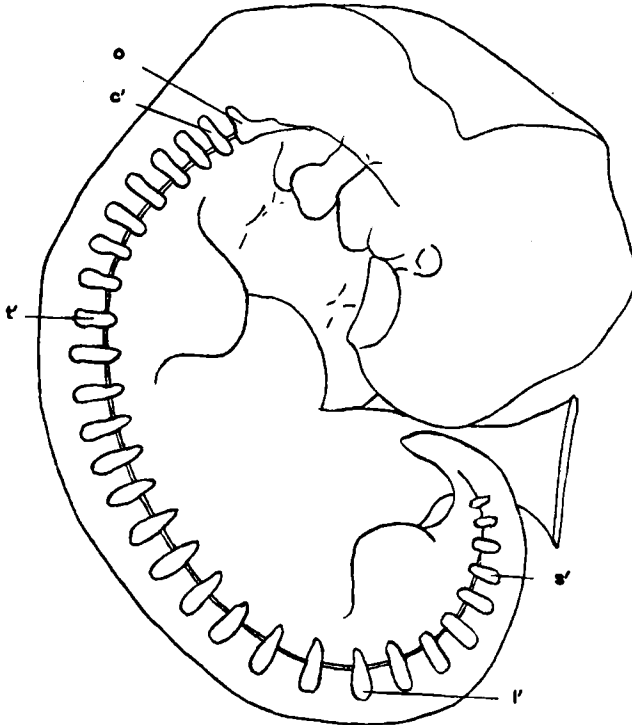

FIG. 1A.

Diagram of the vertebral column of an embryo 7½ mm. long and about four weeks old.

o, occipital plate.   t', first thoracic scleromere.
c, first occipital scleromere.   s', first sacral scleromere.
                    l¹, first lumbar scleromere.

and they very quickly fuse with the cartilaginous transverse processes. Usually they bear no close resemblance to the true ribs (see figures by Charlotte Müller, 1906). The centers for the costal elements of the first one or two lumbar vertebræ may appear a little earlier and fuse a

little later with the transverse processes than those of the other lumbar vertebræ, but they are not, it seems to me, to be classed as ribs and the vertebræ to which they belong classed as thoracic or thoraco-lumbar, unless they bear so strong a morphological resemblance to the ribs as to seem to come in series with these. This normally is not the case. There is usually a sharp change of form from the twelfth thoracic rib to the costal element of the first lumbar vertebra. As a rule there are no separate centers of ossification for the costal elements of the lumbar vertebræ. In twenty embryos less than one hundred days old studied by Mall (American Journal of Anatomy, 1906), in which the other ribs were present, there were no centers of ossification for the twelfth rib in eight instances. In no instance was there a separate center of ossification for a thirteenth (first lumbar) rib. In two instances there were separate centers of ossification for a cervical rib.

There is, it seems to me, no evidence of an ontogenetic reduction of the distal portion of the thoracic region.

Sacral Region.—This region becomes distinct during the sixth week owing to the fusion of the distal ends of the blastemal costal processes to form a lateral sacral plate. Separate chondrogenous centers for the costal elements frequently, if not constantly, arise, but they quickly fuse at he base with the cartilaginous transverse processes of the neural arches. Laterally the cartilaginous costal processes become united to one another within the blastemal lateral sacral plate. The processes of the first three sacral vertebræ usually become thus united before the third is joined by the fourth and the fourth by the fifth. Judging from Rosenberg's studies, the processes of the second and third vertebræ frequently become united before being joined by those of the first sacral vertebra, but this is by no means constantly the case. I do not agree with Rosenberg that the first sacral vertebra must be called a lumbo-sacral vertebra until the ends of its cartilaginous costal trans-verse processes are intimately fused with those of the second sacral vertebra. In early embryonic development the surrounding blastema must be taken into account.

Coccygeal Vertebræ.—These first become distinct from the sacral vertebræ during the latter part of the sixth week, when the ends of the costal elements of the sacral vertebræ become united by blastemal tissue. It is, however, by no means always easy to distinguish the sacro-coc-cygeal boundary at this period because the transverso-costal elements of the first coccygeal vertebræ are relatively well developed and may

become united by strands of connective tissue with those of the last sacral. The thirtieth vertebræ at this period should not, however, be counted as an integral part of the sacrum unless the costal elements really help to form the lateral sacral plate. When cartilage unites the ends of the costal elements of the sacral vertebræ into a cartilaginous lateral sacral plate it becomes easy to distinguish the sacral from the coccygeal vertebræ. If the costal elements of the thirtieth vertebra are united by cartilage to the twenty-ninth it becomes a sacral vertebra, but not otherwise. This condition is not infrequent in embryos, but it must be remembered that sacra with six vertebræ are frequently found in the adult. It is uncertain whether or not the costal element of the first coccygeal vertebra normally has a separate center of chondrification. It is fairly certain that no such centers are found in the other vertebræ.

During the period of ossification separate centers usually appear for the costal elements of each of the first three sacral vertebræ. It is said that these centers may appear merely in the first two vertebræ. They may appear in all five.

In conclusion, I may say, it seems to me, that the data at present available go to show that regional variation in the embryonic vertebral column corresponds approximately with that in the adult. A study of a large number of embryos correlated with a study of vertebral variation in the race from which the embryos came is necessary before accurate data on the subject can be obtained.

OBSERVATIONS ON THE SALIVARY GLANDS OF MAMMALS. By
    Robert R. Bensley. *From the Department of Anatomy, University of Chicago.*

Although much progress has been made in recent years in studying the changes that present themselves in the cells of the salivary glands in the different stages of their functional activity, no successful attempt has been made to subdivide the general classes of mucous and serous or albuminous glands into subordinate categories. It was pointed out that any such subdivision must be on physiological or biochemical grounds, because of the lack of fundamental differences in the structure of the protoplasm of glandular cells. Such differences as appear are rather concerned with the mode of aggregation, appearance, staining and microchemical reactions of the stored up secretion-antecedents and their various prophases. Accordingly, in studying glandular cells, it is

of first importance to learn the characters presented by them in the living condition. For this purpose it was pointed out that the fluids usually employed as indifferent fluids are not truly indifferent, and that this need is best filled by the blood serum of the animal under investigation obtained by centrifugation of freshly defibrinated blood. In the study of fixed material it is of the first importance to secure a method of fixation which will retain in the cell the antecedents of the secretion, if possible in the form in which they are present in the living cell. The latter is not always possible, but even where the form of these antecedents is altered in the fixed material, if the substance is retained it may be available to discriminative staining reactions, or to microchemical reactions. The order of procedure, then, in an investigation of a salivary gland from this standpoint is: (1) The examination of the fresh material in blood serum, using teased preparations, or sections cut with a Valentine knife. For this purpose freezing methods must be avoided, as they produce profound changes in the form of the secretion antecedents. (2) Experimental fixation to obtain a method which preserves the secretion antecedents in the form which they have in the living cell. (3) The examination of the fixed material to establish definite and differential microchemical reactions or staining reactions for the secretion antecedents.

Proceeding in this way, the writer has been able to obtain certain results which seem to justify the subdivision of the serous class of cells into a number of subordinate groups. To one group belong the demilune cell of the submaxillary glands of the cat and dog. In the fresh condition, examined in blood serum, the secretion of these cells is seen to be in the form of granules, of small size, but of so low refractive power that only by the use of the best apochromatic lenses can they be seen. In this respect these granules are much less easily seen than the low refractive granules of the mucous cells. The secretion when fixed in aqueous sublimate or in Zenker's fluid does not stain by any method which has been applied, and sections from such material stained in toluidene blue show the mucous secretion metachromatically stained, but no metachromatism is visible in the demilune cells. Staining with muchæmatein and mucicarmine is positive for the mucin antecedents, but negative as regards the secretion of the demilune cells. On the contrary, when the tissue is fixed in Orth's formaline bichromate mixture or in Kopsch's mixture the secretion is retained in the demilune cells, although not in the granular form it presents in the living cells.

In these preparations the secretory content of the demilune cells stains metachromatically in toluidene blue or saffranin, thionin, etc. The metachromatism of the demilune secretion is often more intense than that of the mucous content. No other substances stain metachromatically in these preparations but the secretion of the demilune cells and mucous cells and the granules of mast cells. In these Orth and Kopsch fixations also the secretory content of the demilune cells of the cat stains with muchæmatein and mucicarmine, applied according to the directions of the writer in former papers on glands. This metachromatism produced by special fixation the writer proposes to call tropochromatism, and to designate cells which are capable of giving this reaction tropochrome cells. In addition to the demilune cells of the submaxillary gland of the cat and dog the so-called clear cells of the submaxillary gland of the rabbit, rat and gopher belong to this category of tropochrome cells. Other serous cells, as, for example, the demilunes of the horse's submaxillary, fail to give any metachromatic reaction, whatever the form of fixation. Examined fresh in serum, these cells exhibit the characteristic highly refractive granules of zymogenic cells. These granules are easily fixed by solutions containing formalin or mercuric chloride, and when fixed are readily stained by neutral gentian iron hæmatoxylin, etc., but show no metachromatism when fixed in Orth's or Kopsch's fluid and stained with toluidene blue, etc. Such cells the writer proposes to call homochrome. This being a negative character, it follows that the homochrome group of cells are likely to prove heterogeneous in character and to be subdivisible into other subordinate groups. This has been in part accomplished by the writer, and the results will be communicated in the complete paper to be published shortly.

THE TRUE RELATION OF THE OLFACTORY NERVES OF MAN, DOG AND CAT. By Effie A. Read. Presented by Simon H. Gage. Cornell University.

In all of the works on comparative and veterinary anatomy it is stated that the olfactory nerves have a plexiform arrangement. In no animal examined was this found to be the case. In the dog and cat, where the examination was most complete, the olfactory nerves form a fan-shaped expanse. On their way from the olfactory cells in the nasal mucosa to the olfactory bulb they converge, forming larger and larger bundles before they traverse the cribriform plate. The bundles may cross one another, but there is no plexus of nerves formed.

In man, from the time of Scarpa (1785) until the present (1907), all figures and descriptions of the olfactory nerves emphasize the plexiform arrangement. This appearance is most striking in the superior concha, as the nerves traverse canals in the bone instead of being spread out on the surface, as with the dog and cat. Differential staining showed, however, that there was no true nerve plexus. The abundant connective tissue ensheathing the nerve bundles and lining the bony canals and the blood vessels frequently form plexiform unions, but not the nerves. Each neuraxone in man, as in the lower animals, is then independent from the olfactory cell to the glomerulus of the olfactory bulb.

AN ANALYSIS OF THE OLFACTORY PATHS AND CENTERS IN FISHES.
By RALPH EDWARD SHELDON. *From the Laboratory of Anatomy, University of Chicago.*

In the brain of the carp, Cyprinus carpio, the olfactory nerve passes from the mucosa to the olfactory bulb in two bundles, forming the olfactory fibers of the first order. From the bulb tracts of the second order run through a long crus to the olfactory lobe. From the lateral part of the bulb arise four tracts which end in the lateral olfactory nucleus of the same and opposite side. From the caudal portion of this nucleus, the nucleus tæniæ, runs the tractus olfacto-habenularis to the habenula ending in the opposite side. From the habenula run two tracts, Meynert's bundle to the corpus interpedunculare for motor correlation and also a tract to the region of the nucleus rotundus. From the middle of the bulb arise two tracts which end in the mesal olfactory nucleus of the same side. Thence a tract runs to the nucleus rotundus and the hypothalamus. On the mesal side of the bulb arise several tracts which join, going to the lateral olfactory nuclei of the opposite side, to the mesal olfactory nuclei of the same side, to the epistriatum and perhaps to the hypothalamus and nucleus rotundus. A portion of this bundle also forms the interbulbar commissure. There is also a commissure connecting the two lateral portions of the forebrain, lying in the caudal part of the precommissure. From a nucleus just caudad of the commissure, the nucleus preopticus, a tract runs ventro-caudad to the hypothalamus. The central part of the basal lobes forms the striatum from which a large tract, the tractus strio-thalamicus, runs to the hypothalamus and the nucleus rotundus region. From the hypothalamus is a large ascending tract, the tractus epistriaticus, ending in the epistriatum of the opposite side.

Considering that gustatory tracts enter the hypothalamus and that tracts leave it for motor centers, it is very probable that an important function of the hypothalamus is to act as a correlation center for taste and smell and to furnish connections for these with the motor centers. The region of the nucleus rotundus is evidently concerned to a great degree with the correlation of the olfactory sense with the motor centers. The forebrain is partly a secondary olfactory center and is probably also a correlation center for taste and smell through the ascending tract from the hypothalamus.

THE NERVOUS SYSTEM OF THE AMERICAN LEOPARD FROG, RANA PIPIENS, COMPARED WITH THE EUROPEAN FORMS, RANA ESCULENTA AND RANA TEMPORARIA. By HENRY H. DONALDSON, *The Wistar Institute, Philadelphia.*

From observations on these three species it appears that they are similar in general form and proportions, but that Rana pipiens has:

1. A heavier central nervous system, 11-12 per cent.

2. A heavier brain and spinal cord (the spinal cord in R. temporaria is nearly the same as that in R. pipiens).

3. A heavier brain in relation to the weight of the spinal cord.

4. A greater percentage of water in both the brain and spinal cord.

5. A larger number of medullated fibers in the spinal nerves.

6. A slightly greater proportion of sensory fibers. (5. and 6. When compared with R. esculenta.)

7. Shorter internodes, calling for a larger number of sheathing cells. (When compared with R. temporaria.)

These characters may all be counted to the credit of Rana pipiens, as indicating a slightly higher development of the nervous system.

The full statement of these results will appear shortly in the Journal of Comparative Neurology and Psychology.

A STUDY IN THE GAIN IN WEIGHT FOR THE LIGHT AND HEAVY INDIVIDUALS OF A SINGLE GROUP OF ALBINO RATS. By ELIZABETH H. DUNN. *Department of Anatomy, University of Chicago.*

While weighing some fifty groups of albino rats at various ages from birth to fourteen days, it was noted that while the averages of various groups differed rather widely, the individuals of a single group did not depart far from the average for that group unless there existed a single very heavy or very light individual.

A group that showed rather wide variations within itself attracted attention at about the eighth day after birth, and since the members of the group seemed equally healthy, it was thought that this difference in weight was a prenatal and not a postnatal difference, and that a study of the increase of weight in such a group might be suggestive.

Weighings were instituted on the fourteenth day and continued every third or fourth day until laboratory conditions vitiated the findings.

The initial weights at fourteen days, the weights at twenty-three days, when the young became practically independent of the mother, and the weights at sixty-six days, about sexual maturity, were selected for tabulation. The percentages of gain at these dates on the basis of the initial weight at fourteen days were included.

	Grams at 14 days.	Grams at 23 days.	Per cent of gain.	Grams at 66 days.	Per cent of gain.
Rat 1 O.........	20.1	29.8	48	72.5	260
Rat 2 O.........	17.1	24.5	41	67.3	293
Rat 3 O.........	16.3	27.1	66	64.8	298
Rat 4 O.........	14.8	21.5	45	53.5	261
Rat 5 O.........	13.3	21.6	57	63.5	363
Rat 6 O.........	12.8	21.9	70	52.7	310
Rat 7 O.........	11.8	19.8	68	53.8	356

As previously ascertained, the average weight at fourteen days for both males and females is 15 + grams. The average for this group is 15 + grams, while the extremes are ten grams apart.

The average daily gain for the white rat is 1 + grams. The average gain for Rat 1 of this group was 1 + grams and for Rat 7.9 — grams, therefore the daily gain for the individuals of this group indicates their normal condition.

The percentage gain for the individual rats shows that the lighter rats, while putting on a less absolute weight, had at the end of sixty-six days gained a greater percentage of their original weight than had the heavier individuals.

The following table should be substituted for the table, on page 109 of Vol. II, accompanying Miss Dunn's Abstract—A Study in the Gain in Weight for the Light and Heavy Individuals of a Single Group of Albino Rats.

	Grams at 14 days.	Grams at 23 days.	Per cent of gain.	Grams at 66 days.	Per cent of gain.
Rat 1 ♂.........	20.1	29.8	48	72.5	260
Rat 2 ♂........	17.1	24.5	41	67.3	293
Rat 3 ♀........	16.3	27.1	66	64.8	298
Rat 4 ♀........	14.8	21.5	45	53.5	261
Rat 5 ♀........	13.3	21.6	57	63.5	363
Rat 6 ♂........	12.8	21.9	70	52.7	310
Rat 7 ♀........	11.8	19.8	68	53.8	356

This is the correct form for the table printed on p. 109 of Vol. II of the Anatomical Record.

The findings may be summarized as follows:

Rats in a litter tend to maintain their original order relations as to weight, extra heavy rats maintaining their ascendency.

Lighter rats in a litter while having a less average daily gain in weight have an actual greater daily gain when their initial weight is considered, that is, their percentage of gain is greater.

The actual differences in weight at successive periods tends to increase, as do the percentage relations.

These findings hold true for the litter as a whole and for each sex considered separately.

THE NUCLEI OF ORIGIN OF THE CRANIAL NERVES IN THE 10 MM. HUMAN EMBRYO. By G. L. STREETER. University of Michigan. With two Figures.

Through the kindness of Dr. Huber, the writer had the opportunity of making a study of the nervous system in an unusually good 10 mm. human embryo, for the use of which he takes pleasure in acknowledging his obligation. The embryo had been cut in a faultless series of 5 micra sections and the tissues were in an excellent state of preservation, making it especially well adapted to purposes of reconstruction. The brain and the cranial and cervical nerves were reconstructed in wax after the Born method, and the following paper refers to some of the findings:

This stage in the growth of the brain is particularly interesting in that it represents what might be called a primitive or primary brain. The primary neurones of the cranial and spinal nerves, including their peripheral extensions into the muscle masses and central extensions into the wall of the brain tube, are already well laid down, and, in fact, what we see in brains at this time is almost entirely this primary apparatus. The higher receptive and co-ordinating tracts are still in a rudimentary state. It is before the development of the olive, the pontine nuclei and the cerebellum; and the forebrain still consists of a thin-walled neural tube, showing but little sign of differentiation.

In contrast to the retarded state of growth of the higher centers, the spinal and the third to twelfth cranial nerves have advanced so far in their differentiation that their appearance closely resembles the features of the adult. Due to this precocious growth of the cranial nerve elements the rhombencephalon furnishes one-half of the bulk of the entire brain. Peripherally it is possible to trace out the complicated com-

munications between the cranial nerves and the formation of the cervical and brachial plexuses. The characteristic communication, for instance, between the first cervical and hypoglossal nerves, with the consequent *descendens hypoglossi,* is already established, and it can be seen how the latter unites with the combined branch from the second and third cervical nerves forming a typical *ansa hypoglossi,* from which branches can be seen entering the muscle masses of the hyoid group. It is likewise possible in this embryo to trace the nerve roots centrally into the brain and outline the nuclei of origin of the motor roots and follow the extension of the sensory roots up and down in the wall of the neural tube.

In the reconstruction it is these structures that have been modelled out, and thus there is represented of the centripetal elements the dorsal funiculi of the spinal cord, and the spinal tract of the trigeminal nerve and the fasciculus solitarius of the seventh, ninth and tenth cranial nerves. Of the motor elements there is the nucleus of origin, which forms a continuous column of cells extending from the spinal cord into the brain. This column is longitudinally subdivided into a median and lateral column. The median column gives off rootlets ventrally, including the ventral spinal roots and hypoglossal nerve, and, placed at intervals more cephalad, the abducens, trochlear and oculomotor nerves. The lateral column gives off rootlets leaving the lateral part of the tube, including the motor elements of the spinal accessory, vagus, glossopharyngeal, facial and trigeminal nerves.

The so-called rhombic grooves, or transverse furrows, which are present at this time in the floor of the fourth ventricle, can be definitely made out in the model. That these grooves are a true feature of growth in the mammal and are not artifacts is an opinion that has been accepted with much conservatism; but, now that they have been reported in the pig, rabbit, dog, sheep, cat and rat, and recently by Mrs. Gage in the human embryo, there can no longer be any doubt as to their reality. The writer gave them an ultimate test in the pig by examining the fresh embryo while still warm in its own amniotic fluid, and under the binocular microscope it could be seen that the grooves had the same characteristics that are present in preserved specimens.

In the model there are six distinct rhombic grooves, which correspond closely with those seen in the living pig embryo by the writer and with the description published by Bradley (1905, Jour. Anat. and Physiol., Vol. XL) of the preserved pig embryo. These commence in the region

of the pontine bend and extend caudad. Their shape, comparative size and arrangement is indicated in the accompanying Fig. 1.

Their relation to the cranial nerves is likewise indicated in the same figure. If the grooves are labelled *a, b, c, d, e* and *f,* then it can be seen that we have the following relations: the trigeminal nerve arises conjointly from *a* and *b,* the facial nerve runs transversely beneath the floor of groove *c,* which usually is the deepest and most sharply cut of all six grooves, the acoustic nerve has its attachment to the
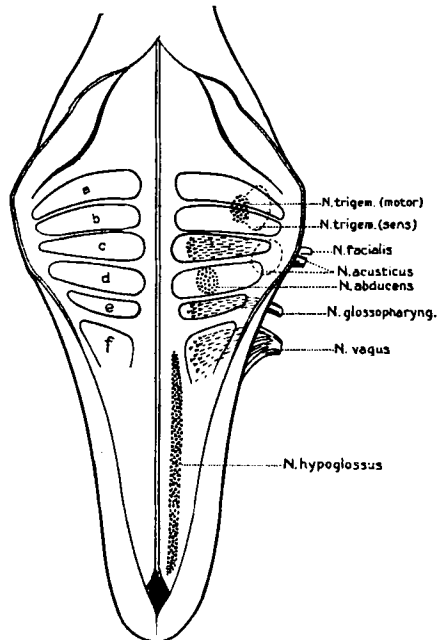

FIG. 1. Diagram of the floor of the fourth ventricle in the 10 mm. human embryo (Huber embryo No. III) illustrating the rhombic grooves and their relations to the cranial nerves. The point of attachment of the acoustic and the sensory root of the trigeminal nerve is shown by dotted circles; the motor nuclei are represented by heavy dots.

marginal plate adjoining grooves *c* and *d,* the abducens nerve arises from *d,* a shallow and somewhat quadrilateral groove, the glossopharyngeal nerve runs under the floor of the narrow groove *e,* and the vagus arises from *f,* which groove merges caudally into the general floor of the ventricle.

This nerve distribution is constant in the different mammals, and it is very likely that in this we have an explanation of the significance of these grooves. The predominant view regarding them heretofore has been that they are neuromeric and in a series with the spinal segments and the coarser transverse divisions of the mid- and forebrain. Instead of this, if emphasis is laid on the fact that they stand in constant relation to the lateral group of cranial nerves (fifth, seventh, ninth and tenth), then they may be fitted in with and form part of the branchiomeric system. This view has in its favor the fact that they are not only united by nervous trunks, but also numerically correspond to and are embryologically contemporary with the branchial and facial arches, in a manner shown in the following table:

Maxillary Process	Trigeminal N.	.... Groove *a*.
Mandibular Arch		.... Groove *b*.
Hyoid Arch	Facial N.	Groove *c*.
	Abducens N.	Groove *d*.
Third Branchial Arch	Glossophar. N.	Groove *e*.
Fourth Branchial Arch	Vagus N.	Groove *f*.

The one discordant feature is groove *d*, which has no corresponding branchial arch. It is possible that this should be considered, not as a true branchiomeric groove, but as simply the interval between grooves *c* and *e*; or, on the other hand, we may in this instance have to do with a displaced or lost arch, which is suggested by the aberrant course of the abducens nerve which arises from this groove.

Though the scope of the present communication is not intended to include a more detailed description of the cranial nerves and their nuclei, yet there is one feature regarding the facial nerve and its relation to the abducens nerve to which attention should be directed. It is the reversed relative position which these two structures occupy in embryos at this time as compared with the adult condition. Here the sixth nerve is more caudal than the seventh. As seen in Fig. 1, the nucleus of the facial nerve is situated near the median line under the third rhombic groove, groove *c*, from which nucleus the nerve fibres extend laterally, forming a slightly arched flattened bundle under the floor of this groove, and eventually emerge from the ventro-lateral border of the neural tube near the attachment of the acoustic nerve. The nucleus of the abducens nerve is situated beneath the fourth

rhombic groove, groove *d,* and in some vertebrates is reported as invading the adjoining caudal groove, groove *e.* The nerve fibres of the abducens emerge directly ventral. The entire appearance and behavior of this nerve corresponds with the hypoglossal nerve, with which it is generally considered to stand in serial relation.

As development continues, the floor of the neural tube thickens and the different structures shift their relative position. During this process the abducens migrates cephalad, but, like the hypoglossus, it maintains its relation to the floor of the fourth ventricle. The facial nucleus, however, like the motor nuclei of the ninth and tenth nerves, with the development of the formatio reticularis, is crowded ventro-lateralward. The migration of the nuclei of the facial and abducens nerves and the
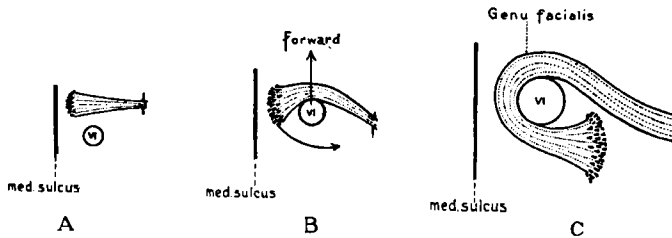

FIG. 2. Diagram illustrating the development of the genu of the facial nerve in the human embryo. The drawings show the right facial nerve and its nucleus of origin, in three stages: the youngest, A, being the 10 mm. embryo, and the oldest, C, the new-born child. The.relative position of the nucleus of the Abducens nerve is represented in outline. Its nerve trunk could not be shown, as the structures are represented as seen from above.

shifting of their relative positions is represented in Fig. 2, in which A corresponds to the 10 mm. embryo and C shows the relation eventually assumed by these two structures in the adult. B represents the intermediate condition, with the directions in which the relative shifting occurs indicated by arrows. It is evident on comparison of the three stages that in case of the formation of the genu of the facial nerve we have to do with a mechanical procedure which is brought about by the forward migration of the abducens nucleus therewith pushing before it the main trunk of the facial nerve. At the same time the genu is extended caudally by a ventro-lateral migration of the facial nucleus.