A Review of the Experiments of John Hunter and More Recent Investigators on Localizing the Areas of Jaw Growth*

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The anatomists of the sixteenth century knew very little about the growth of the bones and until the early part of the eighteenth century little more was added to their meager knowledge. DuHamel was the first to publish anything based on experiments. In 1740 he published a very ingenious theory concerning the growth of bones and endeavored to support this by experiments performed for the purpose of proving that these structures grew by extension of their parts. To give some idea of DuHamel's work, let us select from the number of his ingenious and instructive experiments the one in which he placed a ring of silver wire around the middle of the shaft of the thigh bone of a young pigeon. Later on he found the ring in the medullary cavity of the bone, instead of embracing the exterior of the shaft, where he had placed it.

DuHamel attributed the result of this experiment to mechanical principles, assuming that the bony layers of the shaft of the thigh bone were expanded by the interposition of additional osseous matter, and that the layers were cut through in this process of expansion by the unyielding wire which he had placed around them. All his explanations bear the same mechanical characteristics yet these numerous experiments of DuHamel, which are characterized by much precision and ingenuity, well merit the attention of the student of physiology.

John Hunter was not satisfied with this doctrine and instituted experiments to determine the truth of DuHamel's theory. Hunter explained the phenomena of the ring by stating that "the arteries of the periosteum had deposited new bone on the external surface of the ring, while the absorbents had removed the old bone in contact with its internal surface, by which its relations to the osseous parites of the femur became reversed".

This physiological view of the phenomena, arising out of a knowledge of great and important vascular systems in the osseous frame work was wholly unsuspected by and unknown to the predecessors of Hunter.

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The mode of growth in the mandible was first demonstrated by Hunter who showed, by simple comparison of four half jaws, how the mandible grows at the posterior border. Hunter states:

"As a knowledge of the manner in which the two jaws grow will lead to a better understanding of the shedding of the teeth and as the jaws seem to differ, in their manner of growing, from other bones, and also vary according to the age, it will be here proper to give some account of their growth.

In a foetus three or four months old, we have described the marks of four or five teeth, which occupy the whole length of the upper jaw, and all that part of the lower jaw which lies before the coronoid process, for the fifth tooth is somewhat under that process.

These five marks become larger and the jaw bones, of course, increase in all directions, but more considerably backwards, for in a foetus of seven or eight months the marks of six teeth in each side of both jaws are to be observed, and the sixth seems to be in the place where the fifth was, so that in these last four months the jaw has grown in all directions in proportion to the increased size of the teeth, and besides has lengthened itself at its posterior end and as much as the whole breadth of the socket of that sixth tooth.

The jaw still increases in all points till twelve months after birth when the bodies of all the six teeth are pretty well formed, but it never after increases in length between the symphysis and the sixth tooth, and from this time, too, the alveolar process, which makes the anterior part of the arches of both jaws, never becomes a section of a larger circle, whence the lower part of a child's face is flatter, or not so projecting forwards as in the adult.

After this time the jaws lengthen only at the posterior ends; so that the sixth tooth, which was under the coronoid process in the lower jaw and was in the tubercles of the upper jaw of the foetus, is, at last, viz., in the eighth or ninth year, placed before these parts; and then the seventh tooth appears in the place which the sixth tooth occupied, with respect to the coronoid process and tubercle; and about the twelfth or fourteenth year, the eighth tooth is situated where the seventh was placed. At the age of eighteen or twenty, the eighth tooth is found before the coronoid process in the lower jaw and under or somewhat before the tubercle in the upper jaw, which tubercle is no more than a succession of sockets for the teeth till they are completely formed."

These deductions of Hunter were very remarkable but he was not satisfied by mere comparison. He proceeded to experiment, using the method of madder-feeding. The effect of madder on bone was first described in England by Belchier in 1736.

When madder is added to the food of animals, all new bone formed during the feeding period is colored by the dye to which the calcium phosphate of the bone is supposed to act as a mordant. The bone formed in this period can thus be readily distinguished. Older bone, to the Haversian systems of which additions are still being made, is also lightly colored. The best results are obtained by first feeding with madder and then, for varying periods, without madder. The new bone is then distinguished by being entirely uncolored.

Hunter's works on madderized pigs did not have a very wide distribution but we do know that he disproved DuHamel's theory of interstitial expansion and set up in its place the theory of internal absorption and external addition. But Hunter also discovered the still more important fact that absorption takes place, also, at the external surface of bones. In 1842, Flourens repeated the experiments of DuHamel and Hunter and between them was established the doctrine of internal and external absorption of bone and the further important fact of internal modelling by addition of bone where necessary. This latter fact has recently been emphasized by Todd.

Humphry, in 1864, added the experimental proof to the already well ascertained mode of growth of the ramus. Illustrations from his paper, "On The Growth of The Jaws", published in the Transactions of the Cambridge Philosophical Society, are herewith submitted, along with Humphry's own comments, as follows:

(A) "Lower jaw of a young pig killed one month after two wires had been passed through a hole in the middle of ramus and secured, one around the coronoid and the other round the condyloid edge. The anterior wire projects some distance in front of the bone, whereas the posterior wire is buried deeply in the hinder edge. Figure 1.

(B) "Left side of lower jaw of a young pig. Eleven weeks before it was killed a wire was passed round the ramus. The wire projects in front of the coronoid process, though this is somewhat masked by a horn of new bone having been thrown up on its anterior and outer side. Figure 2.

It is, moreover, buried deeply in the hinder part of the ramus. Indeed the ramus looks as if it had been cut more than half through by it and had thus yielded a little to the pressure upon it, so acquiring a preternatural slant backwards.

(C) "Right side of the lower jaw of the same pig. Two months before it was killed, a wire was passed through a hole near the anterior edge of the ramus and secured round that edge and a second wire was passed through a hole near the hinder edge and secured round it. The front wire has disappeared; the position which it occupied is marked by a slight thickening at the

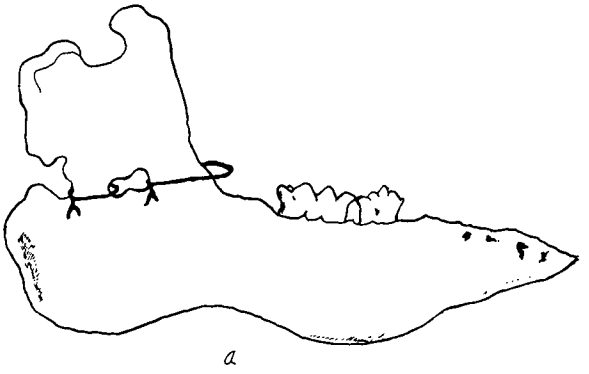

Figure 1 Humphry

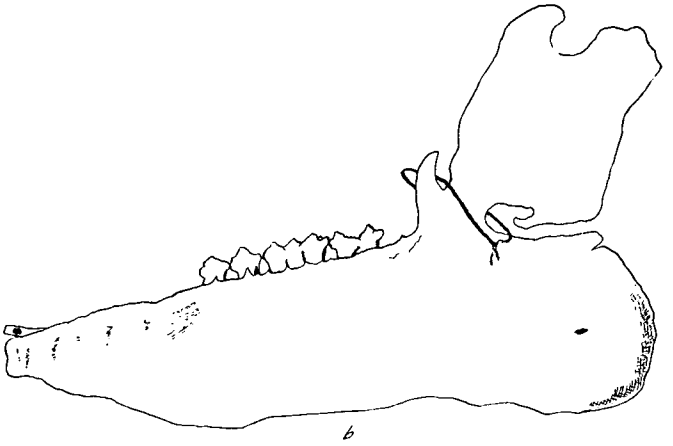

Figure 2 Humphry

root of the coronoid process. The hinder wire still encircling the bone round which it was passed, is at a considerable distance from the hinder edge of the jaw." Figure 3.

Professor James C. Brash has recently made a detailed study of the growth of the skull in pigs by the madder feeding method. His work on the mandible proves conclusively that absorption takes place on the anterior border of the ramus while new bone is added to the posterior surface. He points out, also, that there are active changes, absorption and surface addition, taking place throughout the mandible; but he did find some areas of indifferent action where neither absorption or addition of bone was taking place. The mandible, then, grows by extension of its border in all directions, except along the anterior border of the coronoid process. The extension backwards of the ramus and upwards of the condyle, is noteworthy, as well as the smaller additions all along the lower border.

There can be no doubt that the general features of the growth of the human mandible are the same as those set down by Brash as his findings in the pig's mandible. Kolliker determined the sites of absorption in the mandible of a new born child, microscopically, by the presence of Howslips lacunae and osteoclasts. His work confirms Brash's results.

The growth of the upper jaw and face is a much more complicated process than that of the mandible. This is readily seen when we consider that the mandible is a single isolated bone, as it were, while the upper jaw is a very complex structure made up of many bones. If we compare the skull of a new born child with that of the adult, it is clear that, during growth, expansion takes place in all directions. The questions of where and how this growth takes place will now be considered.

We know that surface apposition, with associated modelling, takes place as in the mandible and, besides this surface addition, there is a very complicated process of addition to the edges of the individual bones at the suture lines.

Brash worked out the mode of growth of the upper jaws by the method of madder feeding on pigs. His findings are applicable to the growth of the human face and the areas and amounts of growth of the bones of the human face have been worked out by Sir Arthur Kieth and Mr. G. G. Campion.

Kieth's and Campion's work was done by comparing, superimposing and measuring skulls of infants and normal adult skulls. Their results are very carefully analyzed in every detail. Time does not permit of going into all the details of their work but we shall relate some of their findings.

Growth Forward

Kieth and Campion noted a forward movement of the nasion of 23 mm. with reference to the external auditory meatus, between the fifth and twenty-fifth years. This was computed by superimposing skulls of these ages by means of the pituitary fossa, which is considered to be relatively unaltered. In analyzing this growth, which takes place between the sphenoid and the occipital behind, and the sphenoid and the ethmoid in front, they also demonstrate a forward and upward movement of the nasion at the fronto-nasal junction of 11 mm. during this period. On a sagittal section of the skull,

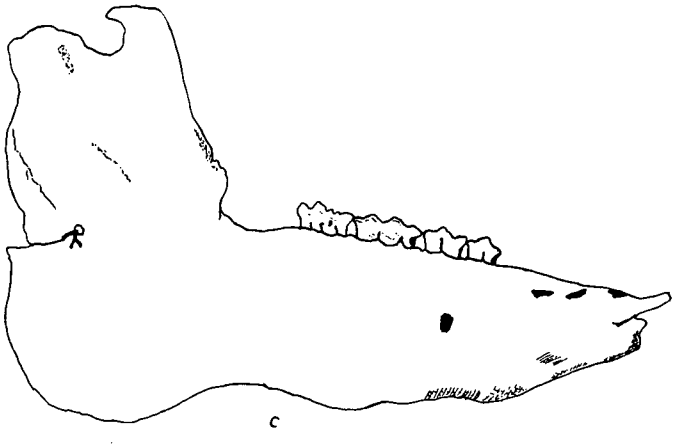

Figure 3 Humphry

Kieth shows three sites of growth along the Nasion-Meatal line. These are the fronto-nasal suture, the spheno-ethmoidal suture and the spheno-occipital suture.

Turning to the lower part of this section, there is the lower part of the coronal system to consider. Kieth and Campion estimate that there is about 9 mm. addition to each pterygoid process and an addition of 16 mm. to the posterior border of each maxilla. The growth of the pterygoid process takes place partly at its sutural junction with the palatine bone and partly at the posterior borders of the two plates, by surface addition, but the addition to the maxilla is, for the most part, on its free surface.

Brash states: "I come to the conclusion that the forward growth of the maxilla is essentially due to increase of its body in both directions, associated with its simultaneous excavation by the expanding antrum and a downward

and forward growth of the alveolar border carrying the teeth. The determination of the more forward position of the whole bone is brought about by the suture growth which takes place at its articulations, but, that this is secondary to the general growth of the surface of the bone is, I think, clear. The main factor in the increase of the antero-posterior depth of the body of the maxilla, free both in front and behind, is not suture but must be surface growth."

Lateral Growth or Growth in Width

Sir Arthur Kieth and Mr. Campion estimate the increase in width at the median, palatal suture at 8 mm. (4mm. on each side) during the eruption of the permanent dentition. The zygomatico-maxillary suture plays an important part in the lateral development of the upper jaw. By the process of absorption on its inner surface and addition of bone to its outer surface, the zygomatic arch is greatly increased in size. This increase is also aided by growth at the zygomatico-temporal suture. The outward movement of the zygomatic arch is, in fact, a good instance of the importance of surface growth. Only in this way can readily be explained the notable differences, racial and otherwise, that occur in the lateral projection of the zygomatic bones and the zygomatic arches.

Growth in Height

Growth in height, from the nasion to the lower margin of the chin, has been placed subsequent to the discussion of growth in the lateral and antero-posterior dimensions of the jaws. This was done because vertical growth is a combination of growth in the antero-posterior plane. There is a swinging downward and forward, as it were, of the face. The alveolar process and the permanent teeth erupting normally have much to do with this increase in height. This, along with general growth of the body of the bones by deposits on their outer surfaces, particularly of the maxilla, accounts for the increase in the downward direction which takes place.

In conclusion, it can truly be stated that much progress in our knowledge of the growth of the bones of the jaws has been made since John Hunter's experiments; that much still remains to be accomplished, no one can doubt. With men like Todd, Krogman, Hellman and Broadbent, of this country, and Kieth, Brash and Campion, abroad, working on the subject much new material and new facts are assured in the not far distant future.

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