

II. ON THE ORIGIN OF THE PULMONARY ARTERIES IN MAMMALS.

BY

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In 1902 I published a paper on this subject,¹ a resumé of which is here given. The pulmonary arteries in man, rabbit, cat, and dog, appear as symmetrical vessels, one rising from each fifth, or pulmonary arch. With the growth of the truncus pulmonalis, and its torsion about the bulbus aortae the two pulmonary arches are wound, as it were, around the bulbus, and their walls thus brought into contact are absorbed, so that the truncus pulmonalis grows longer at their expense, the point of bifurcation moving continually farther from the heart. The left arch, being the outside one in this rolling process, receives the most pull, becomes the straighter and therefore the larger vessel, and is shortened more rapidly. As a result, the point of bifurcation of the truncus pulmonalis reaches the left pulmonary artery while the right pulmonary artery is still seen arising from the right arch some distance dorsal to this point. (See diagram, page 338). The portion of the right pulmonary arch between the origin of the pulmonary artery and the dorsal aorta becomes obliterated, the anterior portion of the arch remains continuous with the artery, and we then have the condition described by Rathke,—the two pulmonary arteries apparently arising together from the left pulmonary arch. It should be noted, however, that the right pulmonary artery of the fetus includes, beside the homologue of the left pulmonary artery, the proximal portion of the right pulmonary arch.

In the pig, although the pulmonary arteries first appear, as usual, as symmetrical offshoots, one from each pulmonary arch; and although the fetal condition is practically the same, the intermediate steps

are different. The two arteries, while their points of origin are still far apart, bend toward each other lower down, and soon anastomose to form a long vessel, connected at its upper end with both the right and the left pulmonary arches, and forking at its lower end to send a branch to either lung. Soon the upper, or proximal, part of the right pulmonary artery becomes obliterated, leaving the common stem in communication with the left arch only, thus forcing the blood to both lungs to pass through the left pulmonary arch.

Since 1902 I have been able, through new acquisitions to the Harvard Embryological Collection, to trace the development of the pulmonary arteries in other mammals,—opossum, sheep, and guinea-

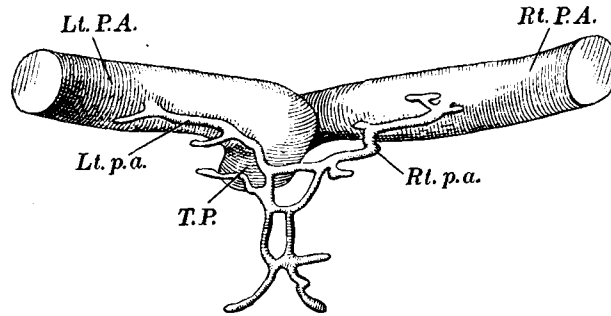


FIG. 1.—Guinea-pig, 7.7 mm. (H. E. C., Series 1512, sections 190-233.) Dorsal view. *P. A.*, pulmonary arches, left and right; *p. a.*, pulmonary artery; *T. P.*, truncus pulmonalis. $\times 125$ diam.

pig, and to make a few observations on the cow and deer. In the opossum and sheep the picture is essentially the same as in man, rabbit, cat, and dog, though in the sheep the two pulmonary arteries are brought to the bifurcation at almost the same time, so that very little of the right arch plays a permanent rôle in the right pulmonary artery. In the guinea-pig, on the other hand, the development of these arteries follows very closely that described in the pig, but with one important difference. In both animals the arteries originate as symmetrically placed vessels from the right and left pulmonary arches, in both they bend toward each other and anastomose, and in both the upper end of one pulmonary artery, from the arch to the anas-

tomosis, becomes obliterated, leaving the anastomosis and the lower ends of both arteries connected with only one arch. In the pig the left arch remains in communication with the combined pulmonary arteries, in the guinea-pig the right; in the pig the entire right pulmonary arch from the bifurcation of the truncus pulmonalis becomes

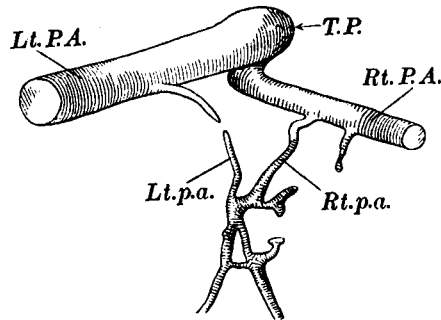


FIG. 2.—Guinea-pig, 8.0 mm. (H. E. C. series 1513, sections 277-315.)
× 125 diam.

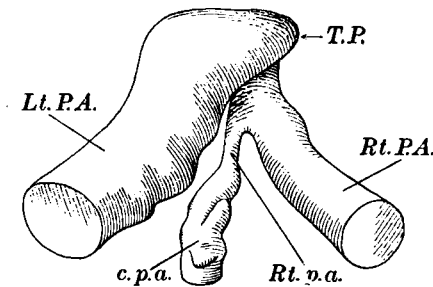


FIG. 3.—Guinea-pig, 8.2 mm. (H. E. C. series 770, sections 230-256.)
c. p. a., conjoined pulmonary arteries. The lower portion of the pulmonary arteries not shown. × 125 diam.

obliterated, in the guinea-pig the anterior part of the arch, as far as the origin of the right pulmonary artery, becomes incorporated in the adult pulmonary artery, and only the posterior part is lost.

Minor differences of development occur in the two animals, as may be seen by comparing the accompanying drawings with the figures of pig embryos in the former paper. The pulmonary arteries in the guinea-pig are seen to form a meshwork of capillaries and to preserve

their irregular course even after the upper part of the left artery has become obliterated. From the beautiful injection of the blood vessels of embryos made by Dr. H. M. Evans of the Johns Hopkins Medical School, it is probable that in all embryos the pulmonary arteries, in common with all other small arteries, arise at first by a capillary network, and that only later the main channels become larger and free from the surrounding capillaries. Remnants of this capillary origin of the pulmonary arteries are not infrequently seen in embryos, as for instance the short vessel from the right arch in Figure 2, loop formations near the pulmonary arch, side twigs from the arteries, even (in one instance in a sheep embryo of 10.0 mm., H. E. C. series 1340, sections 398-409) an artery which is double throughout most of its course, making a very long loop. In the guinea-pig this early condition lasts longer than in the pig or the other mammals studied,—the pulmonary arteries are later in straightening out and becoming distinct channels.

Another minor difference lies in the fact that, although in both pig and guinea-pig the two pulmonary arches are wound about the bulbus aortae as described above, in the guinea-pig there seems to be no fusion (or at least a much delayed fusion) between the two, so that the truncus pulmonalis is not lengthened, as in other mammals, at the expense of the two arches; the two arches merely lie one below the other, side by side. This is shown in Figure 3, in which the left arch is seen to overlap the right for a considerable distance; if fusion had taken place, as in the pig, the pulmonary artery would already seem to spring from the bifurcation instead of distinctly from the right arch as in the drawing.

In 1904, two years after my first article, Sakurai published a paper in which he describes the growth of the pulmonary arteries in the deer.² The original starting point is the same, two symmetrical buds, one from each pulmonary arch; but the left pulmonary artery, according to this author, moves toward the bifurcation of the truncus pulmonalis, and then continues farther to the right until it arises distinctly from the right arch, near to the origin of the right artery.

²Anat. Anzeiger, Band XXV, No. 14, p. 321, 1904.

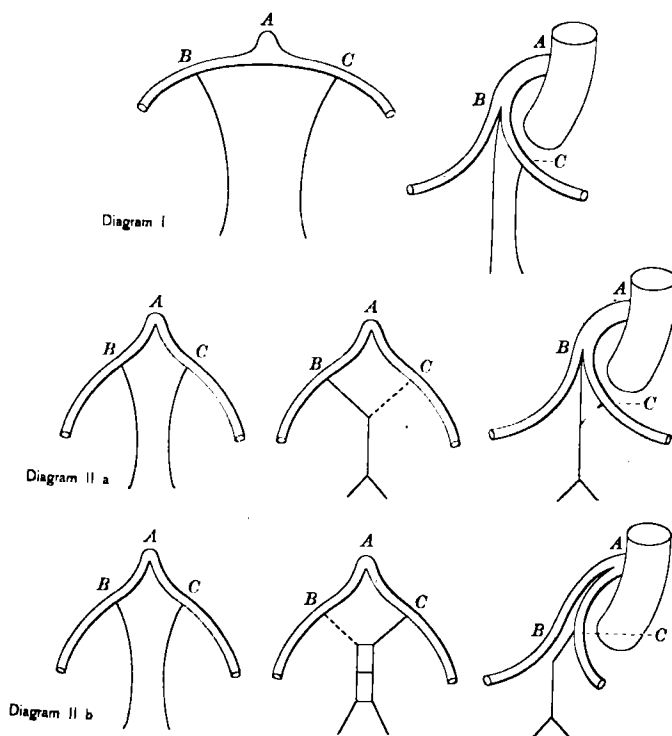


DIAGRAM I.—Shows the original symmetry of the pulmonary arteries, and, in the second figure, the result of the torsion about the bulbus aortæ. A, truncus pulmonalis, at the point of the original bifurcation; B, point on left pulmonary arch where the left pulmonary artery rises; C, same for right side.

DIAGRAM II.—(a) In the pig; shows the original symmetry, the pulmonary arches less wide spreading, the arteries nearer together. In the second figure, the anastomosis of the arteries, and in the third figure, the result of torsion. (b) Same for the guinea-pig.

I feel obliged to doubt, not the figures in Sakurai's paper, but the interpretation of them. Certainly in the deer³ in this laboratory I find nothing that would lead one to suspect that the deer differed from man, rabbit, sheep, cat, or dog in the development of its pulmonary arteries. In embryos up to 9.8 mm. in length the picture is the usual one, the two pulmonary arteries approaching each other as the bifurcation of the truncus pulmonalis is brought farther dorsal; and in an embryo of 18.6 mm. (H. E. C., series 1230), whose general characteristics show it to be younger than the oldest figured by Sakurai, the left pulmonary artery is seen arising from a short stem common to it and the right pulmonary artery. The posterior part of the right pulmonary arch no longer exists. The arteries are well established, with thick walls, so that any migration would seem impossible. A short common stem for the two pulmonary arteries in the fetus is not uncommon, and I should prefer to interpret Sakurai's last figure as an unusual lengthening of this common stem rather than as a migration of the left artery along the right arch, especially as the landmark, the posterior part of the right pulmonary arch, is lacking.

If we accept this interpretation of Sakurai's figures, the different methods of the development of the pulmonary arteries so far reported fall into two main groups, one of which may be subdivided. (1) In man, cat, dog, rabbit, sheep, cow, deer (?), and opossum the development may be described by Diagram I. (2) In the pig and guinea-pig the development differs from that of the other mammals mentioned, and may be shown roughly in Diagram II, (a) representing the pig, (b) the guinea-pig.

In this curious grouping of the animals studied, generic lines seem to have no influence. In my former paper it was suggested that the large size of the auricles in the pig embryo caused the crowding together of the pulmonary arteries and their consequent anastomosis, and I again offer this explanation. In the guinea-pig also the auricles are very large at the time when the pulmonary arteries

³*Cervus capreolus*. The laboratory is indebted to Professor Franz Keibel for the embryos.

are growing, but there seems to be no crowding of the tissue surrounding the trachea from the sides. The mechanism seems to be slightly more complicated. The large auricles and large sinus venosus separate the trachea posteriorly from the bulbus aortae and the truncus pulmonalis anteriorly more, it seems to me, than is usual in animals without the large auricles. The aortic arches are straightened out more, the figure they present with the bulbus or truncus becomes more like a Y than like a tuning fork, and hence the pulmonary arteries, starting out at right angles to the pulmonary arches, point toward each other instead of backward, as in other animals. This purely mechanical result of large auricles seems to me to account for the difference of development between the pig and the guinea-pig and all other mammals studied. The cause of the larger auricles I do not know; nor can I explain why, after the anastomosis, the left artery in one case, and the right in the other, should remain permanently.