VII. *On the Existence of Four Distinct Hearts, having regular pulsations, connected with the Lymphatic System, in certain Amphibious Animals.* *By* JOHN MÜLLER, *M.D. Professor of Physiology in the University of Bonn. Communicated by* LEONARD HORNER, *Esq. F.R.S.*

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I HAD long observed that it was very easy to obtain lymph from frogs, because these animals have large lymph-spaces (Lymphräume) immediately under the skin, and between the muscles. If the skin of the thigh of a frog be cut, the lymph will flow pretty freely, and may be collected in a watch-glass: it will continue fluid for ten minutes, and then coagulates; it is at first as clear as water. By this means, lymph can be exhibited to students, a matter of some importance, for medical men have very rarely an opportunity of seeing it, in the whole course of their lives; and the word has been very inappropriately applied to many heterogeneous things. Whether all the hollow spaces observed under the skin of the frog be true lymph-spaces, appears to me to be doubtful; several of them, however, most decidedly are so, especially those of the thigh.

None of the other amphibia have so large lymph-spaces as the frog has, but they all appear to be provided with remarkable *pulsating organs*, which direct the motion of the lymph. These I first observed in the frog.

1. *Posterior Lymphatic Hearts of Amphibia.*

These are most easily found in the frog, but they exist also in the toad, the salamander, and the green lizard; probably in all amphibia, the naked as well as those provided with scales. The organ is double, and, in the frog, lies on each side, behind the articulation of the os femoris, next the anus, in the regio ischiadica. Its regular contractions may be seen even through the skin, but more distinctly when that over the part is removed. The organ lies immediately under the skin. The arteria and vena ischiadica, the largest vessels in the thigh, run

immediately underneath the organ, but the motion of the blood in those vessels has no influence upon it. The contractions are neither synchronous with the motions of the heart, nor with those of the lungs, and are peculiar to the organ; for they continue after the removal of the heart, and even after the dismemberment of the animal. The pulsations of the two organs, on the right and left sides, do not keep time together, but sometimes alternate at irregular intervals. The organ is about two lines long, in the direction of the length of the animal, and about one line in breadth. When it contracts, it assumes an appearance as if it were separated into distinct compartments, and its internal surface has a spongy cellular structure. The fluid which moves in it is certainly not blood, but clear colourless lymph. If an incision be made into the organ, and air be blown into it, in the direction of the lower extremity of the animal, all the connected lymph-spaces of the thigh and leg are filled with air. These lymph-spaces in the thigh, lie partly under the skin, and partly between the muscles, and coming from the anterior and posterior sides of the thigh, they unite in several large lymphatic trunks behind the organ, and through these trunks the organ itself can be inflated. The inflation of these trunks, or of the organ, fills with air a large lymph-space lying under the skin, at the posterior external part of the abdomen, and another of the same kind between the abdominal muscles and the peritoneum, in the same situation on each side. Sometimes also a large lymphatic vessel, having a very thin coat, becomes filled; this leads, in an upward direction, to the arteria iliaca, appears to come in contact with that on the other side, and ascends further towards the aorta abdominalis, like the ductus thoracicus; but this vessel cannot be further inflated in an upward direction, and it is possible that the lymph, from the posterior part of the abdomen, goes to the posterior lymphatic heart, while the lymph from the intestinal canal and anterior portion of the abdomen goes to the anterior lymphatic heart. If the lymphatic heart be inflated, in the direction of the upper extremities of the animal, a superficial lymphatic vessel becomes filled, which proceeds from the back into the organ. At the entrance of all these lymphatic vessels there appear to be valves, so that distention does not always take place when the organ is inflated. With this exception, the air passes freely from the lymphatic spaces of one side of the animal into those of the other. Neither the lymphatic spaces nor the lymphatic vessels exhibit

the least trace of action in themselves; it is the lymphatic heart alone which pulsates.

The connexion of the organ with the venous trunk of the thigh, on the same side, is very remarkable; for it appears clearly to conduct the lymph of the hinder extremities, as well as that of the posterior part of the abdomen and of the back, into this venous trunk.

I must here make some observations upon the posterior part of the venous system of the frog. The veins of the hinder extremities are, the vena cruralis and the vena ischiadica, and these unite above the thigh by a large transverse anastomosis. The vena iliaca is the continuation of the vena ischiadica, then becomes the vena renalis advehens Jacobsonii, which passes into the kidneys after receiving branches from the posterior region of the abdomen. The transverse anastomosis of the vena cruralis and ischiadica passes, in the regio pubis, into the vena abdominalis anterior impar, so that both cross veins unite in a semicircle, from the middle convexity of which the vena abdominalis anterior springs, while the extremities of the semicircle pass behind, into the venæ ischiadicæ. The vena abdominalis anterior receives the blood of the abdominal muscles, and, as happens in all amphibia, passes to the vena portæ of the liver. Thus the blood of the posterior part of the body does not immediately reach the vena cava inferior, but, according to JACOBSON, first passes through the vena advehens of the liver, and the venæ advehentes of the kidneys*.

The venæ advehentes of the kidneys, the vena abdominalis anterior cum venâ portæ become filled with air each time the lymphatic heart of the regio ischiadica is inflated, while the air passes into the vena ischiadica which lies under the lymphatic heart, through a venous branch, and then passes further, partly into the vena renalis advehens of this side, partly through the venous semicircle into the vena renalis advehens of the other side, and into the vena abdominalis anterior. This connexion of the lymphatic heart with a branch of the vena ischiadica is seen very perceptibly whenever an incision is made into the organ, and it is injected with quicksilver by means of a steel syringe. In that case, all the above-named veins become filled with quicksilver.

The posterior lymphatic hearts are somewhat difficult to find in the sala-

* For an account of the venous system of amphibia, see JACOBSON in MECKEL's Archiv für Physiologie, 3 band, 1817, p. 147.

mander and lizard, because their skin adheres very firmly; but in these animals they also lie under the skin, at the root of the tail, in a lateral position, behind the os ilium.

2. *Anterior Lymphatic Hearts of Amphibia.*

In a paper inserted in POGGENDORF's Annalen der Physik, 1832*, I alluded to the discovery I had made of the *posterior* lymphatic hearts; the *anterior* lymphatic hearts I only lately discovered. I read in an English medical journal that Dr. MARSHALL HALL, the author of a valuable work entitled "Essay on the Circulation of the Blood, London, 1831," had observed an artery in the frog, which continued to beat after the removal of the heart. It immediately occurred to me that this might also be the indication of the existence of a lymphatic heart; I procured the original work, which was only known in Germany by a short extract from it in FRORIEP's Notizen, and I then saw the figure of the injected artery in that meritorious book. Dr. HALL's observations are entitled to much respect, but he has, in this case, been deceived; and the proofs which he conceived he had thereby obtained of the muscular contractility of the arteries, rest on no better foundation than others which have been brought forward. The pulsating vessel in that place is a vein, and indeed a branch of the vena jugularis; and its pulsations are produced by a lymphatic heart which is connected with the vessel, and sends lymph into it. If the lymphatic heart be cut, the pulsation of the vein in question instantly ceases.

The anterior lymphatic hearts lie on each side, upon the great processus transversus of the third vertebra. The organ is found at once if the scapula be carefully raised and partly cut away. It lies immediately under the posterior end of the scapula, and partly projects beyond the posterior edge of the processus transversus of the third vertebra, so that it can be seen from below, although not so conveniently. It is of a round shape, and anteriorly somewhat pointed where it is connected with the vein in question; it is almost as large as the posterior lymphatic heart. The fluid which is sent from it into this vein is colourless; the transparency of the organ shows very clearly that it is so. This vein receives at the same time its blood from fine venous branches, which run above and beneath the organ, and even pass over it. At

* Beobachtungen zur Analyse der Lymphe des Blutes und des Chylus.

the moment of contraction of the lymphatic heart, the vein is the most distended, because it then receives the lymph; but when the lymphatic heart is relaxed, the vein collapses, and becomes more slender. If the lymphatic heart be injured, no further alteration takes place in the diameter of the vein. The lymphatic heart receives the lymph of the anterior part of the body, and probably also that of the intestinal canal, in order to send it into this vein. If an incision be made into the organ, and if it be inflated, immediately lymphatic spaces in the axilla become filled with air. By blowing in a direction towards the head, this vein, which I have said receives lymph from the organ, is filled with air; and if the organ be injected in the same direction with quicksilver, by means of a steel syringe, this vein, and through it the vena jugularis, as far as the vena cava superior, will be filled with quicksilver. The vein which proceeds from the organ forwards, in a direction parallel to the columna vertebralis, is, like most other veins, of a blackish colour, and unites with a vein of the occiput. The small trunk produced by this union, viz. the vena jugularis, now descends, receives venous branches from the scapula and from the axilla, and finally receives a vein of the region of the throat, and then ends in the vena cava superior, at the place where a great vein of the arm also enters the vena cava superior. This vein of the arm conducts a great part of the blood of the arm back, and receives a large vein of the skin of the trunk. The vena cutanea is remarkable on this account, that the blood of the skin of the abdomen arrives almost through it alone at the vena cava superior, while the blood of the abdominal muscles passes through the vena abdominalis anterior to the vena portæ, and from the posterior part of the abdomen into the venæ renales advehentes. The branches of the vena cutanea which go to the vein of the arm, come from the inferior and lateral part of the skin of the abdomen, and from the back. Smaller branches of the same vein unite behind with veins which go to the venous system of the thigh.

I have never discovered a trace of motion in the cysterna chyli and ductus thoracicus of mammalia.

In the vascular system of the blood, there certainly are particular places, besides the heart, which are capable of contractions; as for example, the bulbus aortæ in fishes and batrachia, the venæ cavæ where they enter the atrium, and the pulsating organ discovered by Dr. Marshall Hall at the end of the

vena caudalis of the eel, where that organ receives the venous branches of the extremity of the tail, and conducts its blood into the vena caudalis. But organs of pulsation in the lymphatic system have hitherto been altogether unknown; it is not probable that they should exist only in amphibia, and important discoveries of a like nature in the higher animals, such as birds and mammalia, may be expected;—my researches, as regards these, have however been hitherto unsuccessful.