

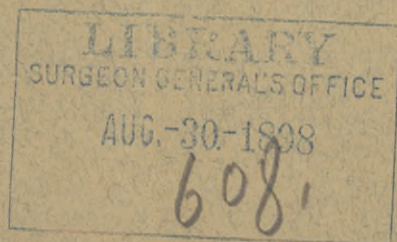
Hopkins (by S.)
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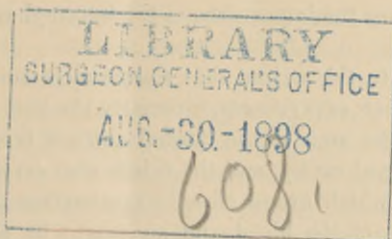
The Heart of Some Lungless
Salamanders.

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ZOOLOGY.

The Heart of Some Lungless Salamanders.¹—The recent literature of zoology has, perhaps, contained nothing more unexpected and startling than that certain adult salamanders are entirely lacking in those respiratory organs which, heretofore, have been deemed indispensable to the existence of animals so high in the zoological scale as the Amphibia. This total lack of lungs and branchiæ appears the more marvelous when we remember that they are absent in forms which lead a rather active and wholly terrestrial life, as well as in those of more or less purely aquatic habits.

Two questions are naturally suggested by this apparently aberrant condition of the respiratory organs. First, what structures or organs have taken on the functions of the lungs and branchiæ? and secondly, is there any modification in the form or structure of the heart which in any way may be correlated with the above mentioned peculiarities of these lungless forms?

The first of these two questions has been discussed to some extent by Prof. Harris H. Wilder, of Smith College, who first published an account of this apparently anomalous condition. He concluded that respiration was probably carried on by the skin and, perhaps, to some extent, by the mucosa of the intestine. Prof. Camerano has also published the results of some experiments upon two European forms which bear upon this same question. He believes that in these lungless forms respiration is effected in the bucco-pharyngeal cavity, and that the skin affords no efficient aid in the respiratory processes.

In a still later paper he discusses the subject further, and tries to account for the disappearance of the lungs. Of one aquatic species (of the genus *Molge*) he says: "The function of the lungs as hydrostatic organs, is very marked." "In the clearly terrestrial forms one would say that the diminution in importance of the function of the lungs as hydrostatic organs induces a retrogressive development of them while

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at the same time the importance of the bucco-pharyngeal respiration is increased."

It appears to the writer that Camerano's conclusions need to be tested by further experiments, especially the part referring to the respiration, for the area of the dermal surface far exceeds that of the bucco-pharyngeal cavity, and the skin is also very richly supplied with blood vessels which are so close to the surface that it would appear as if the gases of the blood and air might be readily interchanged. It is hoped that time will permit of some experiments on this point during the coming year.

As to the second question, whether there is any appreciable modification of the heart in these lungless salamanders, nothing whatever has been published.

It is the object of this paper to call attention to the fact that there is a difference in the heart of those salamanders that do not have lungs and those which do have them. So far as I have examined, it is possible to distinguish between the two forms by examining the heart alone.

In order that what is said on this point may be clearly understood by every one, and in order to bring out the differences between the two more sharply, if possible, I wish first to recall to mind the structure of the Amphibian heart and then contrast with it the relations as found in the heart of a lungless individual. We may take Huxley's description of the Amphibian heart as our standard of comparison. In his *Anatomy of Vertebrates* he says: "The heart presents two auricles, a single ventricle and a bulbus arteriosus. A venous sinus, the walls of which are rhythmically contractile, receives the venous blood from the body and opens into the right auricle. The left auricle is much smaller than the right and a single pulmonary vein opens into it." In regard to the septum of the auricles, he says that "it is less complete in *Proteus*, *Siren* and *Menobranchus* (*Necturus*) than in other Amphibia. In *Menobranchus* the septum is reduced to little more than a wide meshed network of branched muscular bands, and in *Proteus* the existence of a septum is doubtful."

The heart of our common Newt (*Diemyctylus viridescens*) Fig. 1 or of the large yellow-spotted salamander (*Amblystoma punctatum*), for examples, corresponds perfectly with Huxley's description. In both of these forms the auricular septum is perfectly complete, the cavities of the auricles being entirely separated, except just at the auriculo-ventricular aperture, at which point the two auricles communicate with each other to some extent.

In *Necturus*, the septum is more or less fenestrated and, according to Huxley, it is very incomplete in *Proteus* and *Siren*, but in all of the

forms that have been mentioned, as well as in other members of the class Batrachia, the sinus venosus opens distinctly into the right auricle and the pulmonary vein into the left.

Let us now compare the heart of a lungless salamander (Fig. 2.) with the one just described. The four parts, auricles, ventricle, bulbus arteriosus and sinus venosus are clearly recognizable and, superficially examined, present nothing unusual; it is only when the cavities are opened that the differences between the two hearts become apparent. One of the first things to attract attention is the left auricle. In the lungless forms examined, it is much smaller in comparison to the right than in *Diemyctylus*, for example, and *no pulmonary vein was found opening into it.*

The auricular septum has only one opening through it, or perhaps, more correctly, it extends only part way across the cavity, but this aperture in the septum is so large (Fig. 2, 9.) that it is believed the communication between the two cavities is more free than even in *Necturus*. Just what function or functions the septum may have in these lungless forms, it seems to me, is not quite clear. That it has but little, if any use, is indicated by the way the sinus venosus opens into the auricles. In place of opening into the right auricle only, as in the forms having lungs, *it opens more freely into the left auricle than into the right.* If the ventral parietes of the heart be removed, one can look directly into the opening of the sinus venosus from either of the auricles, but more directly into it from the left than from the right, for when seen from the latter, one must look through the large opening of the auricular septum, Fig. 2, 9. In salamanders with lungs, each auricle opens in common into the ventricle with about equal freedom of communication, whereas in the lungless forms the right auricle is in more direct communication with the ventricle than is the left.

Judging from the above facts, i. e., the way the sinus venosus opens into the auricles, the freedom with which the auricles communicate with each other, and the way the auricles communicate with the ventricle, it would seem as if the heart of the lungless salamanders, functionally, was only bilocular in place of being trilocular as in the rest of the Amphibia. Morphologically, of course, it is trilocular, but whether it is so physiologically seems to me doubtful.

The heart of 8 lungless species have been examined by the writer, and so far as was made out, all of them agree closely with the description as given above. The probabilities are that in all the lungless forms similar conditions of the heart will be found. Up to the present time 17 species and sub-species, either wholly without lungs or with only

functionless rudiments of them, have been reported. In his last paper, in which are enumerated 15 of the 17 lungless species, Wilder says that "in the Salamandridæ lungless species are as numerous as those possessing lungs, and that in consequence of this, the definition of the group must be modified." It seems, however, that even with his proposed additions, the definition is still not sufficiently comprehensive, for the peculiarities in the structure of the heart certainly have almost as profound a significance as the absence of the lungs themselves, and should be incorporated in any definition that may be given. In addition to the 17 lungless species already mentioned, the writer has found an additional one, *Spelerpes gluttolineatus*.

In order that one may see at a glance in which families and genera lungless individuals are found, the following table, taken from Prof. Cope's *Batrachia of North America*, is appended. [The last column is taken from the papers of Wilder and others].

| Families. | Genera. | No. of species. | No. species without lungs or with only rudiments of them. |
|-----------------------------|--|---|--|
| Cryptobranchiidae | { Cryptobranchus Megalobatrachus | 2 1 | |
| Amblystomidae | { Amblystoma Chondrotus Lingualapsus Dicamptodon | { 12 [N. A.] 1 [Siam] 7 2 1 | 1 <i>A. opacum</i> |
| Hynobiidae [all Asiatic] | { Hynobius Salamandrella Onychodactylus Ranidens Batrachyperus | 5 2 1 3 1 | |
| | { Plethodon Hemidactylum | 8 1 | 2 { <i>P. cinerus</i> <i>P. erythronotus</i> <i>P. glutinosus</i> |
| Plethodontidae | { Batrachoseps Stereochilus Autodax Geotriton Gyrinophilus Manculus | 4 1 3 ? [European] 1 2 | 1 <i>B. attenuatus</i> 1 <i>A. lugubris</i> 1 <i>G. fuscus</i> 1 <i>G. porphyriticus</i> 1 <i>M. quadridigitatus</i> |
| | { Spelerpes Oedipina | 9 3 | { <i>S. bilineatus</i> <i>S. ruber</i> <i>S. gluttolineatus</i> |
| Thoriidae | { Oedipus Thorius | 9 1 | 1 <i>O. variegatus</i> |
| Desmognathidae | { Desmognathus | 3 | 1 { <i>D. fusca</i> <i>D. f. brimleyorum</i> <i>D. f. auriculatus</i> |

PLATE XVI.

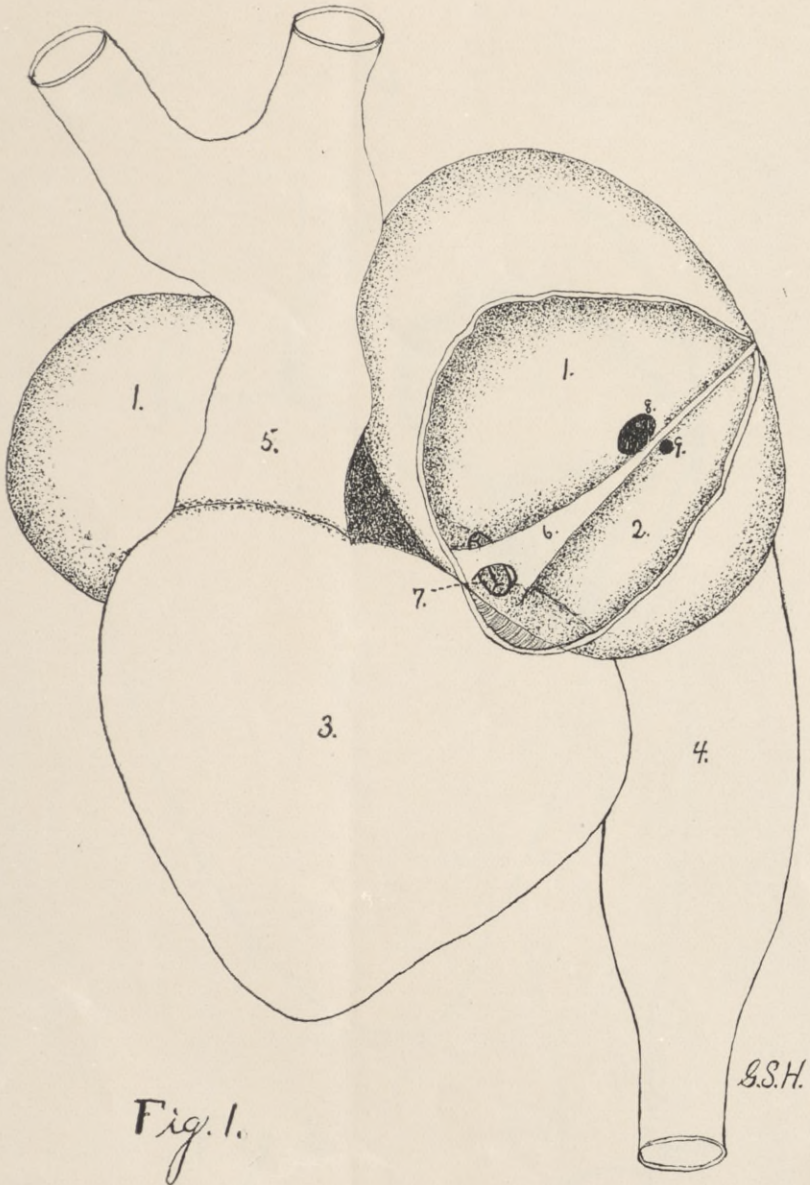


Fig. 1.

PLATE XVII.

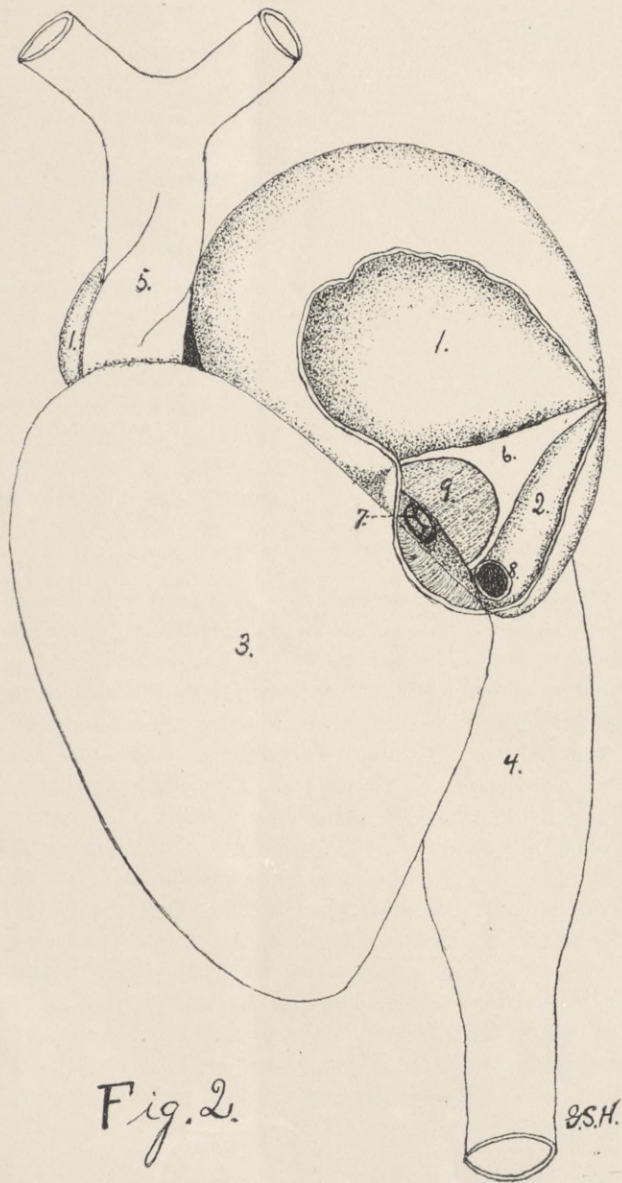


Fig. 2.

Hopkins on *Desmognathus*.

| Families. | Genera. | No. of species. | No. species without lungs or with only rudiments of them. |
|---|----------------|-----------------|---|
| Salamandridae [Old World] | Chioglossa | 1 | |
| | Salamandra | 3 | |
| | Hemisalamandra | 1 | |
| | Triturus | 6 | |
| | Pachytriton | 1 | |
| Pleurodelidae [All found in Old World; three species in N. A.] | Salamandrina | 1 | 1 <i>S. perspicillata</i> |
| | Diemyctylus | 10 | [2 N. A. species] |
| | Pleurodeles | 1 | |
| | Glossolega | 3 | |
| Amphiumidae | { Amphiuma | 1 | |
| Coeceiliidae | { (numerous) | (numerous) | |

In the last column of the above table, the figures indicate the number of species in which lungless individuals have been found. Where there is a discrepancy in the numerals and the number of species following them, it indicates either sub-species or species not mentioned in Cope's *Batrachia* of North America.

DESCRIPTION OF FIGURES.

FIG. 1. Heart of *Diemyctylus viridescens* (semi-diagrammatic) to show the general relations of the heart of a salamander with lungs. The ventral wall of the heart has been removed in order to show the auricular septum, the openings of the sinus venosus and the pulmonary vein, and also the relation of the auriculo-ventricular aperture to the right and left auricle.

1. Right auricle; 2. Left auricle; 3. Ventricle; 4. Sinus venosus; 5. Bulbus arteriosus; 6. Auricular septum; 7. Auriculo-ventricular aperture; 8. Aperture of sinus venosus; 9. Pulmonary vein.

FIG. 2. Heart of *Desmognathus fusca* (semi-diagrammatic) to show relations of the heart in a lungless salamander. The ventral wall of the heart has been removed.

1. Right auricle; 2. Left auricle; 3. Ventricle; 4. Sinus venosus; 5. Bulbus arteriosus; 6. Auricular septum; 7. Auriculo-ventricular aperture; 8. Aperture of sinus venosus; 9. Opening through auricular septum.

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