

fossorial forms, i. e. *Corystes* and certainly others besides, the reversal of the circulation becomes, on the contrary, accentuated, and renders possible the adaptation of the ambulant forms to this new mode of life. In the case of *Carcinus mœnas* it enables the animal to live amid unwholesome surroundings by the introduction into the branchial chamber of air at a pressure even higher than that of the atmosphere\*.

### III.—On the Reversal of the Respiratory Current in the Decapods †. By GEORGES BOHN ‡.

THE reversal of the current of water in the branchial chamber, which has long been known in the case of *Corystes* and was recently described by me in *Carcinus mœnas*, Leach, and a certain number of other Decapods §, appears to be a phenomenon of absolutely general occurrence in this group of Crustacea. Mr. Garstang lately published an account of it in *Portumnus nasutus*, Latr., and I have just proved its existence in twenty-one other species selected from the various families ||. I thought it would be interesting to note the frequency and the duration of the inversions in the different cases, and I now give the principal results that I have obtained.

The frequency of the inversions varies little from one type to the other: most frequently they occur at the rate of two per minute; in one and the same species the number appears to diminish in proportion as the size increases; thus, in the case of *Carcinus mœnas* there are on the average ten inversions

\* The occurrence of this reversal appeared to me to have its bearing on the comprehension of the adaptations that are found in the Decapods; M. Bouvier, who has lavished his learned advice upon me in the course of my investigations upon this group, of which he has so wonderful a knowledge, pointed out a fact of the same kind a few years ago. He explained the adaptation of these crustaceans to terrestrial life as being due to an ancestral anatomical and physiological condition—to wit, the *supplementary circulatory system* (the special circulation of the carapace).

† A study carried out at the marine laboratory of the Muséum at Saint-Vaast-la-Hougue.

‡ From the 'Comptes Rendus,' t. cxxv. no. 15 (October 11, 1897), pp. 539-542.

§ 'Comptes Rendus,' Sept. 13, 1897, pp. 441-444; *vide supra*, p. 17.

|| I propose to return later on to the mechanism of the process of reversal; at present I will simply say that the principal rôle seems to devolve upon the scaphognathite, and that in certain types the carapace intervenes; as for the cleansing organs (epipodites of the crabs, posterior limbs in *Galathea*, &c.), I have proved that they do not take any part in it.



in the *Megalopa*-larva, and in the course of growth this number diminishes progressively until it sinks to one.

The *duration* of the inversions is often very brief—about the hundredth part of a minute; but in a certain number of species, such as *Carcinus mænas*, it may be much greater than this. I have established in the case of each species the following number—to wit, the duration of the inverse circulation in the space of ten minutes—counted in hundredths of a minute \*, and the results of my investigations are summarized in the appended table (p. 22).

In consequence of Prof. Giard having pointed out to me the importance of the phenomenon of reversal for the comprehension of the ethology of the parasitic forms, I was led to establish the following curious parallelism.

We know that the crustacean branchial parasites of Decapods are the Entoniscidæ, *Cepon*, *Bopyrus* (sensû stricto), and a few Copepods.

Entoniscidæ, the ethology of which has been so admirably elucidated by MM. Giard and Bonnier, have frequently been met with upon a *Porcellana* found upon the shores of Brazil, in *Carcinus mænas*, and in *Portumnus latipes*, Penn., which lies buried in the sandbanks on the shore at Wimereux. Now *Carcinus mænas* and *Porcellana longicornis* (which also has its Entoniscid) are the only species—species not related moreover—in which I have found for the inverse circulation a number most nearly approaching 500 (that is to say, 5 minutes in 10). *Portumnus latipes* is nearly allied to *Portumnus nasutus*, in which the reversal, as described by Mr. Garstang, is so strongly accentuated. In *Portunus*, *P. arcuatus* is apparently the only species able to exhibit periods of reversal of fairly long duration. Now this species is infested with Entoniscidæ much more frequently than *P. ruber* and *P. holsatus*. Among the Oxyrhyncha, *Achæus*—a genus allied to *Stenorhynchus*—is the only one that has been found to support an Entoniscid. In *Pilumnus hirtellus* these parasites are equally rare. Thus, except the latter, all the hosts mentioned † belong to the third category of the table.

*Cepon*, as M. Giard caused me to observe, is not met with

\* This number, which is necessarily approximate, corresponds to the issue of carmine from the region of the latero-posterior inspiratory cleft of the carapace, which is the easiest to observe—that is to say, the one which is situated in front of the first thoracic limb. I have taken the hundredth of a minute, since it frequently corresponds to a beat of the scaphognathite, which I am therefore able to use as a metronome.

† I have passed over *Xantho* and the Grapsidæ, which I have not yet studied.



DURATION OF THE INVERSE CIRCULATION.	MACRURA.	ANOMURA.	BRACHYURA.
I. More than 10.....	Lobster. Crayfish.	<i>Pagurus Bernhardus</i> , Fabr.	<i>Cancer pagurus</i> , Bell.
II. From 10 to 30 .....	<i>Orangon vulgaris</i> , Fabr. <i>Alpheus ruber</i> , Edw. <i>Palæmon</i> . <i>Hippolyte</i> .	<i>Galathea squamifera</i> , Leach. <i>Gebia deltura</i> , Leach. <i>Callinassa subterranea</i> , Leach.	<i>Hyas araneus</i> , Leach. <i>Maia squinado</i> , Latr. <i>Pilumnus hirtellus</i> , Leach.
III. In which it may be more than 30, and even 100 ( <i>i. e.</i> 1 minute in 10).	..... .....	..... { <i>Porcellana longicornis</i> , Edw. (60 to 200).	<i>Stenorhynchus phalangium</i> , Edw. <i>Portunus puber</i> , Leach. <i>Portunus arcuatus</i> , Leach (120 and over). <i>Carcinus mænas</i> , Leach (60 to 200).
IV. In which it may be more than 900	.....	.....	<i>Portunus nasutus</i> , Latr. <i>Corystes cassidellus</i> , Penn.



in *Carcinus mænas*, in which the reversal is pronounced, nor in *Portumnus latipes* and *Porcellana longicornis*; but it is found in *Portunus arcuatus* and *Pilumnus hirtellus*, which belong to categories III. and II. of the table. *Callianassa*, which is included in the latter category, is infested with *Ionidæ* allied to *Cepon*.

*Bopyrus*, properly so called, is partial to the species of *Palæmon*, *Hippolyte*, and *Galathea*, belonging to category II.

Copepods are rare: they have been met with only in a few examples of *Hippolyte* and in the lobster. Excluding this latter and a few rare exceptions \*, the extreme categories of the table comprise only species which are without branchial parasites.

I have attempted to account for these facts, and it seems to me that the reversal alluded to has both disadvantages and advantages for the parasite.

An inverse current can always eject the parasite in the act of penetrating into the branchial cavity, just as it also expels any strange body whatever. The *Entoniscidæ* alone are able to penetrate in the case of the species in which the reversal is somewhat prolonged; *Cepon* and *Bopyrus* appear much more susceptible in this respect.

But an inverse current, while it cleanses the branchial chamber, causes to pass through it a much more highly oxygenated stream of water, for it is more rapid and the water has not time to charge itself (especially from the well-developed posterior gills) with carbonic anhydride. Here there is an advantage for the parasite; but in the case of the *Entoniscidæ*, in which the respiratory mechanism has been discovered by M. Giard, the advantage is more apparent. In the midst of the animal's viscera the parasite occupies a chamber which is in communication with the branchial cavity of the host by means of a narrow orifice; in consequence of the movements of the abdominal appendages of the parasite the water is drawn in and driven out again alternately. Now in the branchial cavity of the host, which from time to time reverses the circulation of the water, there is a similar alternation: to the inverse current corresponds an increase of pressure of the water in this cavity, which forces the liquid to penetrate into the chamber of the parasite; to the direct current there corresponds, on the contrary, a diminution of pressure, which assists the parasite's expiration.

\* *Pagurus Bernhardus* is infested with a *Palæogyge*, but it is true the latter is very rare.



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