On the Occurrence of Limulus Polyphemus off the Coast of Holland, and on the Transmission of Aquarium Animals.*

By W. A. LLOYD.

IN the summer of 1860 a large number of this creature, Limulus Polyphemus,—the horse-shoe crab, or, as it is called in Germany, the arrow-tailed crab,—was hawked about, in a living state, on a barrow, in the streets of Hamburg, just as I have similarly seen living land-tortoises offered for sale in the streets of London. These crabs have the term "horse-shoe" applied to them because the anterior portion (when the posterior part is bent away from it) much resembles in general form the toe part of a horse's hoof, and "arrow-tail" because the long posterior spine is said to be used by the natives of the countries where it is found for the points of arrows and spears; the point of it precisely represents in its unsymmetrical curve the curve of our modern bayonet of warfare. They are also termed "king crabs," but I do not know why. Their position in the scale of nature is not yet precisely determined. These crabs so seen in Hamburg were obtained from North America by Mr. Hagenbeck, the well-known German dealer in wild beasts and other natural-history objects. They were purchased by many persons, and some were placed in a small marine aquarium in the Hamburg City Museum; others were kept by Dr. Meyer and Professor Möbius in some tanks I had made for them, as at that time I was a dealer in aquaria in London. The interest excited by these crabs and these small aquaria, joined to the interest caused by the aquarium I had recently made in the Acclimatation Gardens in Paris, which was very popular as the greatest and best aquarium then in existence, much advanced the idea of having an aquarium in the Zoological Gardens of Hamburg, then in the commencement of their formation, and all these things together led to my being engaged for aquarium work in Hamburg in the summer of 1862. Naturally enough, there existed a desire, from association, to possess some of these crabs in the Hamburg Aquarium when it was opened, and some arrived in 1865, and lived very well, and were alive when I left Hamburg to return to England in 1870. They all came from New York or its neighbourhood, and the success with which they were brought over led to my getting

* See 'Zoologist,' S. S. 3740, and 'Entomologist,' vi. 529 (with figures).

many more than the Hamburg Aquarium could accommodate, and I was told to put our surplus number in spirits. To me, however, it seems such a horribly cruel thing to plunge into alcohol creatures in the full vigour of life, and it is moreover shockingly inhospitable to do so to foreign animals after they have been brought from their own far-distant countries. So I wrote to aquarium people everywhere, and succeeded in selling or in giving away all we had to spare; and then I issued circulars, printed in English, French and German, begging that no more be imported till further orders. My circular came out too late, however, for on the very next Sunday morning I was asked to call at the house of a captain of a Hamburg and New York steamer to see a lot of these crabs, and I was astonished at beholding a great number, in his garden, walking about and looking like great dully-polished light brown dish-covers marching about by the agency of invisible legs, they being concealed by the shield-like carapace, each with a stiff tail trailing behind it. The sight would have been comical had I not been troubled with the remembrance of the dreadful alcohol, for I was bidden to take charge of the whole lot, for various museums; and I accordingly conveyed them to our Gardens in a four-wheel cab, they filling it as high as the base of the windows, and I, seated outside, was sorely troubled with my charge; but that night I defiantly resolved what to do. I arranged to secretly keep them alive by sprinkling them with water in a cool place till the following Thursday, when the steamer left for London, and this vessel, and two other steamers, had on board (by the kindness of Pearson and Langnese, the owners) free accommodation for natural-history purposes, and, among other things, a one-hundred-gallon cask of sea-water placed on end, with a loose cover on it. On Thursday afternoon, therefore, I drove to the harbour with a cabfull of crabs, emptied the water out of the cask, filled it with the crabs, put on the cover to keep them moist, and saw the steamer off, having previously told a trustworthy and kind man to throw the crabs overboard into the sea when the steamer got fairly into salt-water a little on the British side of the island of Heligoland. This was faithfully done, and I had evidence of it duly furnished to me. It occurred in August, 1866, and I can have no reasonable doubt (in the absence of any evidence showing that others have been since placed in the seas of Northern Europe) but that those which recently were caught on the coast of Holland were either those I thus introduced or their descendants. I may as

well confess that in addition to whatever humane feelings I had in thus saving these animals' lives, and also in seeing whether they would breed under the circumstances stated, there was in the act a little of a spirit of mischief, to see whether British naturalists would squabble at the appearance of living animals so essentially non-European if they turned up in England, and whether, if so, and by what rule, they would be admitted to the British Fauna; and I am rather disappointed at finding there has been no more "fending and proving" than there has been over the matter.

It is interesting to go into the reason why these and some other lungless aquatic animals are brought from great distances alive and well, and with ease, while so many other lowly-organized lungless water animals are transported with such great difficulty. We apply the term "hardy" to such crabs as Limulus; to the Old and New World land-crab (*Gecarcinus*); to the West Indian land hermit-crab (*Cenobita*); to Sesarma, a crab (allied to our English Gonoplax) from the Navigator Islands; to our British shore-crab (*Carcinus*); and to some others, but I name only these five as being those with which I am acquainted in a living state; and by "hardy" we undefinedly mean that these animals are constructed to live for long periods when they are not actually immersed in water, but where they can obtain enough water to keep their gills moist enough for the sufficient aëration of the blood coursing through their gill-filaments; and in accordance with this arrangement all of these five are eminently shore animals.

We are now beginning to learn that, up to a certain point, the value of water for non-lung-breathing aquatic animals does not so much depend on its *amount* as upon its *distribution* in such manner that it shall absorb the greatest quantity of atmospheric air, or rather of the oxygen which enters into the composition of that air, leaving much of the nitrogen out, unabsorbed. The earliest observer known to me of this fact was the late Dr. R. Ball, who, in Bell's 'British Crustacea' (8vo, 1851), records how much better he kept a crayfish (*Astacus*) in a shallow vessel than in a deep one. In all my aquarium work I keep this law in view, and I regulate the amount of surface of water exposed to air, as well as the actual quantity of water, according to the known requirements of the animals to be kept; and the result is very surprising both on the health of the creatures, and in the saving of the money cost of constructing and maintaining aquaria. I also

apply the rule to the *conveyance* of aquarium animals. To give an actual example, I find that the following animals, and some others, may, at certain temperatures, be safely sent from Southend, in Essex, to the Crystal Palace in boxes (or preferably in baskets) packed in damp freshly-gathered sea-weeds:—

1. Nearly all the Sea-Anemones.
2. Most of the Echinodermata.
3. A large number of Annelids.
4. Many Crustacea.
5. Some of the Tunicata.
6. Nearly all shelled Mollusca, both univalves and bivalves, and some of the Nudibranchiata.
7. The following fishes:—Amphioxus (this once came alive from Naples in a post-letter, and four of them so brought are still alive in the Crystal Palace Aquarium), plaice, soles, brill, rocklings, eels, gobies, blennies (of three species), sea-scorpions.

The explanation of the reason *why* they so travel is this: they are surrounded with moisture in a sufficient degree to keep their bodies, in the case of sea anemones, and especially in the case of the specialized breathing apparatus in the other animals, to enable respiration to be carried on. Take, for example, any fish so conveyed. It is not immersed in water, but its gills are kept wet by such very thin films of water that their thinness, otherwise shallowness, enables them to be instantly oxygenated by contact with the atmospheric air, which enters the apertures of the containing box or basket, and which permeates the entire mass, and therefore the gill-filaments are kept wet and separate from one another, and the blood uninterruptedly flows through them and is aërated as it does so, oxygen being absorbed from the perfectly aërated water, which thus does double duty, in a measure. I admit that the balance thus maintained is a delicate one, and is easily disturbed by external causes. Thus a heated atmosphere would cause the moisture to evaporate and the gills to dry up, and the circulation of the blood would be arrested, and the fish or other creature would soon die. So also great cold would freeze the gills into a temporarily dry mass, and death would likewise ensue. It will be observed that many of the creatures I have enumerated never voluntarily leave the water, either in the sea or in aquaria, while others do go out of the water of their own accord, in tanks and in the ocean. But there is one thing which I do not yet understand, and which I should be very grateful to

have explained. It is this, that while many of the creatures I have named will bear the four hours' journey from Southend, some of them will not bear the twelve hours' transit from Plymouth, though equal care be apparently taken with the packing in both cases.* But when such packing is possible, the gain is enormous in every-thing. We often, at the Palace, get a couple of thousand of animals, or more, in packages weighing altogether not half a hundred-weight, while if the same animals needed to be conveyed in properly aërated masses of actual water, each creature would require a pound-weight of water, instead of only a fraction of a grain-weight to each. The money value of the moist plan is strikingly shown in the instance of shrimps, of which we use about a ton weight every year in the Crystal Palace Aquarium for feeding purposes, and we require them alive, because many animals refuse to eat them when dead (when, too, they rapidly decompose and become poisonous), and besides, we are obliged to

* Mr. Herbert Ingall, for whose opinions on all matters I have the highest respect, gives the probably right explanation:—

"In packing animals for travelling in a moistened substance, but to which the air has free access, we would certainly seem to be employing the most effective as well as the most convenient method of sustaining the life of the animals so treated, as the moisture keeps the tissues moist (to a certain extent) in the natural form, so as not to stop the circulation or other vital processes of the living things; the moisture facilitating the respiration by being in thin films, and therefore the more easily they absorb oxygen. In practice this manner of carriage is found to be successful in some cases for very long periods of time, and the question naturally arises,—If an animal so treated can live for four or twenty-four hours, why should the same method not be effective and successful for periods of forty or two hundred and forty hours? To answer this we can but suggest the reasons of the method being unsuccessful for the longer periods, and these suggestions be proved by experiment, as there are no doubt many causes acting together that result in the death of the animal. Let us consider what may be the causes. Least of all we may consider the (in the larger and more active animals at least) undesirable and cramped position that they must necessarily suffer from, and their inability to take food. But the most probable cause of death is this—that the quantity of air and oxygen supplied to the animal being often more than usual, the respiration and vital processes are more rapid, and the waste necessarily greater, as also therefore will be the excretions of the animal. When (and this period will of course vary according to circumstances) the excreta, not being removed, as they would be in the sea, become so great that the oxygen is all required to decompose the organic poisons (for such they are) the animal naturally dies of asphyxia, there being no oxygen available for the respiratory processes, or it may even die of organic poisoning. It is I think *probable* that this is the main cause of death after certain varying periods. Cold would of course retard it by lessening the rapidity of the vital processes. It perhaps might be proved *experimentally* by packing animals in the way described, and causing the removal of the *effete* matter in some way."

keep them in a living state till they are eaten from day to day. They are accordingly brought in baskets measuring eighteen inches long, twelve inches broad, and only two inches deep, and this small thickness enables the shrimps to be well aërated throughout on the journey. I devised this plan, as when they came in high baskets only those at the surface arrived alive. They cost us, in good condition, about a shilling a quart, but if it was necessary to bring them alive, *in water*, they would cost at least a guinea a quart! This system of exposing water to air in a state of exceedingly minute division may be seen in the Crystal Palace Aquarium in a kind of inverse application of the principle, the air as it descends being very finely pulverized in every tank, and all that the water can possibly absorb *is* taken up. It could not be so finely comminuted and diffused if it were made to ascend, and therefore the ascending plan is a very wasteful one.

To return to Limulus. They are brought from America in tubs or boxes containing a layer, two or three inches deep, of wet sand, which is kept moist by having water—sea or fresh water—thrown on it occasionally. Some travelled from New York to Liverpool in a deal-box kept moist by a bladder of water suspended inside it, and in this they again travelled from Liverpool to Hamburg. Some I by accident kept in some badly aërated sea-water in a vessel with steep sides, out of which the crabs could not climb for air. I removed them, apparently dead, and sent them to the City of Hamburg Museum to be put in spirits, but they revived on a cold damp stone-floor, where their gills became oxygenated, and were brought back to the aquarium, where they lived long.

At Professor Owen's request, I sent him some notes on the habits of Limulus in captivity, and he has printed my observations with his own in the Linnean 'Transactions' (vol. xxviii. pp. 471—472), thus:—

"The ulterior pair of limbs are not for walking, but exclusively for burrowing. These limbs are terminated by four long stiff lobes of an oval or leaf shape, jointed at the base, on the leg, and capable of being opened and closed in a four-radiate manner. When it wishes to burrow, these two limbs are, sometimes alternately and sometimes simultaneously, thrust backwards below the carapace, quite beyond the hinder edge of the shell; and in the act of thrusting, the lobes or plates on each leg encounter the sand, the resistance or pressure of which causes them to open and fill with

the sand, a load of which at every thrusting operation is pushed away from under the crab, and deposited outside the carapace. The four plates then close, and are withdrawn closed, previously to being opened and charged with another load of sand; and at the deposit of every load the whole animal sinks deeper into its bed, till it is hidden all except the eyes. The great hiding shield of a carapace again prevents one from seeing whether this excavating work is aided by the fanning motion of the abdominal false feet, as is the case with the British lobster; but I *think* there is such fanning, as I have seen signs of sand being driven through the sand-orifices as if urged by a current of water.

"The tail-spine of Limulus is used in locomotion in the following manner:—The animal having climbed up a rock in the aquarium till it has got near to the top of a tank (which in Hamburg contained thirty inches of water in depth perpendicularly), and having assumed a vertical position, leaves go its hold on the rock, and allows itself to fall backwards; but its downfall is instantly checked, and the creature propelled upwards by a downward flap of all the strong overlapping false feet; and when the impetus given by them has ceased, the animal sinks down, but is prevented from falling prone on the floor of the tank by alighting on the tip of the perpendicularly hanging-down spine. The moment that is done, and before the creature has lost its balance on the spine, the false feet make another flap, and give another impulse upwards and forwards; and so it progresses by a combination of swimming and hopping, or by a succession of slow hops on one leg, as it were; and all this time the position of the carapace is slanting, the top of the carapace inclining downwards at an angle of about 45°, the second segment of the body being at another inclination, and the tail-spine hanging freely vertically, as before mentioned; and by being brought down by its joint at various deviations from the upright one, the spine changes the direction of the march, while the false (swimming) feet effect the actual propulsion. The Limulus was fond of thus going about at night (generally remaining in the sand all day). Another use was made of the tail-spine, as a lever by means of which it righted itself when it fell off a rock on its back. The spine is then bent; *i. e.* its point is planted in the sand, so that it makes an acute angle with the carapace, which is then so far raised that some of the feet are enabled to grasp a projecting surface, either longitudinal or vertical, or at some combination of the two; and the crab then turns over."

Limulus has often caused me to be undeservedly blamed, because they so constantly hid themselves in sand by day in the perfectly aërated water of the Hamburg and Crystal Palace aquaria, while in the imperfectly aërated water of the aquaria of Hanover and Berlin they climbed about the rocks all day, at their surface, and of

course in sight of visitors, because they were seeking for air. So many unthinking people ascribed my inefficient exhibition of these animals to my want of skill, forgetting how many other animals died from the badly aërated water in the places I have named.

Sesarma was brought alive from the Navigator Islands to Hamburg in a slow sailing-ship. It is, as I have already named, a relative of our British crab Gonoplax, which never walks out of water. At first the captain of the vessel put some of his captives in a vessel of water out of which they could not crawl, and the water being but imperfectly aërated, the crabs soon died. So he arranged a box with moist earth and sand, and in this the remaining specimens burrowed, and came out occasionally, and did well. I noticed, without being told by persons or books, that the surface of the pterygostamian regions of the living Sesarma I had in Germany was reticulated, or granulated, by being divided into numerous small regular squares, and that these retained much water by mechanical entanglement. On my telling my friend Dr. F. Hilgendorf, then of Hamburg and now of Yokohama, that I suspected that this arrangement was to enable the crabs to carry about with them their own aquaria of perfectly aërated (because shallow) water, he said it was so, and that some sharp German biologist, whose name I forget, had made the discovery before I did.

Cenobita Diogenes is a powerful West Indian land hermit-crab, living in a univalve shell like our British hermits, but spending much of its time out of water, entering it, I believe, only for depositing its eggs. Yet it is, of course, a gill-breathing animal, needing water to moisten its gills, and so enabling its blood to be purified. How very small the quantity of water it needs may, however, be judged when I say that the first living example I saw was given me by a Swedish carpenter, who brought it from Stockholm in his jacket-pocket, where he had kept it for some weeks previously as a pet. The next I saw was a lot of twenty brought from the mouth of the river Gibarra, in Cuba, to Hamburg in a sailing-vessel. They were found walking about in the burning sun on sand which was all the hotter because black. I went on board to fetch them, and found them in an old cigar-box, which was wrapped in a sailor's "Guernsey" to keep it warm in the hot cooking-place or caboose. Some of the sailors said the crabs fed on tobacco, and others that they ate potato-peel, so both of these substances were placed in the box, on opening which the stench

proceeding from it was awful. But the crabs were alive and well. On opening the window of the cab on my way to the Zoological Gardens, I let in some air, and, the day being very cold, the crabs soon became torpid, and, losing hold of their shells, gradually fell out of them as if dead, and I was in great trouble. I, however, put them in a tray before the fire of the aquarium steam engine, and they soon revived, and, walking about, repossessed themselves of their shells. I afterwards kept them upon damp hot sand, at a temperature of 95° F., and fed them on meat for several months. They would never stop long in the aquarium tanks, but crept out and walked on the floor among visitors.*

Gegarcinus was kept several times in the Regent's Park Zoological Gardens long before there was an aquarium there. The most important thing yet done in this way of comparatively dry transmission was the sending of trout-eggs from Britain to Australia, and there hatching them in such a successful manner that large trout are now found at the antipodes. The eggs were packed in perforated chip-boxes lined with moist moss, and thus the ova had both air and water (a little, but enough, of both) circulating in the interspaces left by the round eggs. In addition, they were kept cold by ice, and the low temperature thus retarded the hatching on the voyage by diminishing the rapidity of respiration, and thereby much lessened the demand for oxygen.

We all know how medicinal leeches—which are, of course, gill-breathing animals—are sent from country to country packed in moist earth, and that enclosed in bags, with no great per-centage of death. Also how eels, periwinkles, mussels, cockles and oysters are transported nearly dry, yet alive and well. Oysters and clams even come to Britain alive from America. Sea-anemones and many other aquatic creatures, including small carp and tench, are frequently sent by post, in moist packing, alive. If these animals had to be transported in water, the weight and trouble would be so great that a trade in them could never be remunerative. What I want, therefore, is to more generally and economically apply to Natural History what has been done for commerce.

* At about the same period there were some Cenobita in the London Zoological Gardens, and I wrote there to know what food I should give mine, and the perfectly serious reply was, "*Oatmeal boiled into hard dumplings!*"

I have written this paper in the hope that it may do good practical service in obtaining for our Crystal Palace Aquarium many marine animals from the splendid aquarium now being constructed, with my help, at Naples; and I trust that Dr. Anton Dohrn, its owner, will soon send us many more animals (in the moist way), in addition to those which—aided by the kindness of shipowners, captains and crews—we have already received from him in water. Dr. Dohrn might re-commence with Mediterranean sea-anemones and crabs, as I believe many of them will survive the overland journey by using care and avoiding large packages. Several packages made up into one is the right plan; and for anemones and some other animals, baskets like our shrimp-baskets, tied six in one, would do very well, I think.

Osphromenus is an oriental fish (Indian, I believe), of which more than one has been brought alive to, and kept at, the Regent's Park Zoological Gardens. I do not know the circumstances of its transmission, nor anything of its habits in England; but, as it belongs to the same family as the "climbing perch" (*Anabas scandens*), I think that, most likely, like the latter fish, its anatomy permits its occasionally living for considerable periods when not actually immersed in water, and of thus being easily sent to long distances. Anabas is provided with an arrangement enabling it to retain a quantity of water for the use of its gills when it is on dry land.

There is another creature (Protopterus or Lepidosiren) which, if a fish, is very closely allied to reptiles, but which in an aquarium is fish-like in its habit of remaining always below the surface of water, and which, if it had to be brought from its home in Africa immersed in a bulk of water, its transport would be so difficult that we should never see it alive in England. But it has been brought in a living state to Britain and to Germany, several times, because in its native haunts it lives in ponds liable to be dried by the sun, and then the creature rolls itself up into a compact ball of mud (hence it is called the "mud-fish"), which becomes hard and dry, yet containing the very small quantity of moisture and oxygen necessary for the animal's almost suspended animation and exceedingly slow breathing, and in this way, the means of oxygenating its gills being readily conveyed about with it, the animal can be sent from one continent to another, easily. On obtaining it, I have gently

broken away the indurated clay or mud and let the contained Protopterus drop into water at a temperature of about 70° F., when it has at once began to swim about as if nothing had happened. But having thus assumed so far the condition of a fish, and having no necessity to again enter a clay prison, it would be exceedingly difficult (I think) to send it back to Africa in water, as its conditions of existence have become quite changed. It would take far too great a space to narrate the instances of my having sent animals of various kinds, marine and fresh-water, of many of the hardy kinds, to various parts of the world, overland and by sea, and of my having received many from similar places; but now, having so good a correspondent as Dr. Dohrn, I hope he will send us many more, he being a good packer.

I find it hard to conclude, however, without telling of one little aquarium brought from Curacoa, in the most perfect manner possible. It consisted of a quart glass jar, its height being twice its breadth. It was half full of sea-water, unchanged during its transit to Hamburg, and six specimens of the mollusk Trochus arrived there in perfect condition, and were kept in the same jar of unchanged water for two years. On the voyage they climbed up the side of the jar, and there had the wash of the water, and they fed on the Algæ which grew quasi-spontaneously. But when large animals *must* be sent long distances in water, as, *e.g.*, Lithodes arctica from Hammerfest, in Norway, to the Crystal Palace, the trouble and cost are enormous, implying for a dozen of these crabs two casks each containing one hundred and twenty gallons of sea-water, with many changes on the voyage and careful supervision all along. If they could be sent in the moist way, their expense would be less than a tenth of what it now is.

In lately reading some observations by Milne-Edwards and Audouin on crabs, I notice that in almost every instance they give accounts of habits only of species which live much out of water and do not need an aquarium for their maintenance.

But about these horse-shoe crabs which I caused to be thrown into the sea, how can I help writing, "Cast thy crabs upon the waters; for thou shalt find them after many days."

W. A. LLOYD.

Crystal Palace, January 5, 1874.