VII. *Experiments to ascertain the influence of the spinal marrow on the action of the heart in fishes.* *By Mr.* William Clift. *Communicated by Sir* Everard Home, *Bart. V. P. R. S.*

Read February 16, 1815.

As the experiments of M. Gallois, which led him to conclude, that the action of the heart is dependent upon the spinal marrow, were principally made upon quadrupeds, in which death is so readily produced, when the vital organs are injured, or any one of them destroyed; I thought by repeating those experiments upon fishes, which are much more tenacious of life, and whose mode of respiration is of a more simple nature, the truth or fallacy of his conclusions might be ascertained.

I was led to select the carp for this purpose, having observed that a carp after the head was cut off, and the heart had been removed for above four hours, and the fish was considered to have been long dead, upon being put into hot water, leaped out of the vessel with a degree of vigour totally unexpected, being equal to the struggles of a living fish.

I shall not take up the time of the Society, by a detail of all the experiments I made, but shall only select those which bear upon this particular subject.

Exp. 1. Two carp of nearly equal size, had their hearts exposed, by opening into the pericardium. In one of them, the heart on exposure pulsated twenty times in a minute, but soon after, only twelve. The fish was put into river water,

in which it swam, with the tail, fins, and gills in full action; in forty minutes the fish turned upon its side, the action of the heart weak, the frequency of pulsations the same; the fins ceased to act, the tail continued to act feebly, the gills strongly.

In an hour, the action of the heart was weaker, the frequency of pulsations the same.

In two hours, the action of the heart and gills was not perceptible in the water, but when taken out and examined, the gills had a feeble action by irregular jerks; the pulsations of the heart were very weak, and rather more frequent.

In three hours, the heart and gills had ceased to act, and the muscles of the body did not contract when stimulus was applied to them.

In the other carp, the heart pulsated eight times in a minute. The fish was laid upon a moist leaden tray. In one hour the pulsations were ten in a minute; in an hour and half, twelve, the fins and tail in full motion. In two hours, the pulsations were a little weaker, but of the same frequency. In three hours and forty minutes the action of the heart ceased. The gill covers acted fifteen minutes longer.

Exp. 2. Having exposed the heart of a carp as in the former experiment, the pulsations were found to be eight in a minute. In eleven minutes, a red hot wire was passed from the tail to the occiput, so as to destroy the spinal marrow; the action of the heart was immediately quickened for three beats; then a long pause, after which the pulsations were the same as before. All action ceased in the muscles behind the pectoral fins, and those muscles did not contract, when stimulus was applied to them.

In one hour from the laying open the pericardium, and five minutes from the passing of the wire, the pulsations had the same frequency.

In twenty minutes after passing the wire, the pulsations were strong, and fifteen in a minute.

In forty-five minutes, the pulsations were twelve in a minute, exactly corresponding with those of the heart of the carp laid on the wet tray, in which the spinal marrow remained entire.

The brain was now exposed, the pulsations became fifteen in a minute, but in five minutes were only twelve. The brain was then extracted, the pulsations of the heart were not sensibly affected either in strength or frequency. The gills and mouth had no longer the least degree of action. In two hours from the beginning of the experiment, the pulsations were fifteen in a minute.

Turning the fish always accelerated the action of the heart a little.

In three hours, the pulsations were the same.

In four hours, they were twelve in a minute.

In five hours, they varied from twelve to six in a minute.

In six hours, they were six in a minute.

In seven hours, nine in a minute.

From this time the action of the heart was very slow and weak: In eight hours and a half, once in a minute.

In eleven hours and forty minutes, they ceased entirely.

Exp. 3. A carp had the heart exposed, by laying open the pericardium: The pulsations were twenty in a minute, but soon were only twelve.

In forty minutes, the spinal marrow at the occiput was cut

through, which increased the action of the heart for three or four beats, which were very violent, and at the rate of twenty in a minute; the pulsations were then twelve as before.

In fifty minutes, a red hot iron wire was passed from the tail to the occiput, and produced strong action in the tail; but from this time, there was no action in the muscles of the body or tail. The pulsations of the heart became a little slower. In sixty minutes they were strong, and twelve in a minute.

The brain was now broke down by a small flat pointed instrument; the pulsations of the heart became twenty in a minute. The gills and mouth from this time ceased to act. The heart went on pulsating with the same frequency as before, but weaker, for two hours, and then gradually ceased; the auricle contracting for more than a quarter of an hour after the action of the ventricle had ceased.

Exp. 4. A weakly carp of nearly the same length with those employed for the other experiments, which was fifteen inches, had the spinal marrow exposed near the base of the tail, and a red-hot iron wire passed along the vertebral canal. All action of the body and gills immediately ceased.

On removing a portion of the skull to expose the brain, the end of the wire was found in the skull, but the brain uninjured. The brain was then entirely removed: no motion was produced in any part of the body or gills.

The body was placed in a wet towel for three hours. The heart was then exposed, its action was strong and distinct in both the auricle and ventricle, at the rate of twenty beats in a minute, but after five pulsations, at the rate of twelve, at which it continued.

At three hours and a half, the action of the heart was weaker

and slower, there being an interval of one second between the contraction of the auricle and ventricle. From the time of exposing the heart no action was perceptible in the branchial artery; it remained of a blue colour, and turgid with blood from its first exposure.

At three hours and three quarters, the pulsations of the heart were only nine in a minute. The interval between the contraction of the auricle and ventricle three seconds.

At four hours, the pulsations were seven in a minute, the interval between the contraction of the auricle and ventricle four seconds.

At four hours and a quarter, the pulsations were seven in a minute; the interval between the contraction of the auricle and ventricle five seconds.

At four hours and a half, seven in a minute; the interval between the contraction of the auricle and ventricle six seconds.

At four hours and three quarters, seven in a minute; the auricle and ventricle acting together.

At five hours, seven in a minute, the interval between the contraction of the auricle and ventricle, one second and a half.

At six hours, the contraction of the auricle seven in a minute, the action of the ventricle hardly perceptible.

At six hours and a quarter, the contractions of the auricle weak: seven in a minute.

At six hours and a half, the auricle ceased to contract; and after this time, no stimulus produced the smallest action in any part of the heart. This experiment was suggested by a notice taken from Dr. WILSON PHILIP'S paper, published in

the Edinburgh Medical and Chirurgical Journal for January last, and made many months after the other experiments.

From these experiments we have the following results:

1. That the muscles of the body of a carp four hours after the brain and heart are removed, can be thrown into powerful action.

2. That the moment the spinal marrow is destroyed, these muscles lose all power of action.

3. That when water is admitted into the pericardium, and the fish allowed to swim about, the action of the heart ceases sooner than when that organ is exposed to air, and the fish kept quiet.

4. That whether the heart is exposed or not, its action continues long after the spinal marrow and brain are destroyed, and still longer when the brain is removed without injury to its substance.

5. That the action of the heart is accelerated for a few beats, by exposure of that organ; by exposure of the brain; injury to the brain; destruction of the spinal marrow while connected with the brain; by the connection between the brain and spinal marrow being cut off: while removing the whole brain produces no sensible effect upon the heart's action, and destroying the spinal marrow after it is separated from the brain renders the action of the heart slower for a few beats.