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A Study on the Pressure Change within the Oral Cavity by the Normal Respiratory Movement and the So-called Cleaning Motion in Carp

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Introduction

In the oral cavity of fish the flow of water over the respiratory surfaces is maintained through the coordinated rhythmical movements of the mouth, operculars. branchiostegals, accompanied with passive opening and enclosing of oral and opercular valves. During inspiration the oral cavity is widened, the operculars are abducted, the oral valves are opened and water flows in through the opened mouth.

During expiration the oral cavity is decreased in volume, the operculars are adducted, the mouth opening is decreased in diameter and closed with passive expansion of the oral valves. Thus the oral cavity communicates with the outermedium through the mouth and the opercular openings supplied with valves and acts as suction- and pressure-pump alternatively during respiration. In higher vertebrates on the other hand the air pump consists of the lungs and a thoracic cage. The thorax is a closed cavity containing two large membranous elastic sacs, communicating freely with outside air through the bronchi, traceas and upper respiratory passages. Increase or decrease in the volume of the thorax is immediately transmitted to the lungs. Air flows in or out of the lungs through the open air passages untill the pressure every where within lungs becomes equal to the external atmospheric pressure.

In this respect fish differs noticeably from the higher vertebrates. This difference has probably evolved from the remarkable difference in the specific gravity of the materials for breathing.

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Therefore some feature characteristic to fish must be found in the pressure change within the oral cavity also.

This paper describes some experiment on the pressure change within the oral cavity of carp.

Method

On the anterior region of the Os frontalis and Parasphenoidium a thin hole was bored through, into which a thin glass tube (diameter 1 mm.) was inserted. The tube was connected with a Marey's tambour through a rubber-tube forming a passage from the oral cavity to the tambour. This procedure was readily accomplished without bleeding.

The fish operated was fixed after the mode described by BAGLIONI (1908) except the anterior ring. The body weight of the carp employed was about 100 g. The fish survived well through and after the experiment.

The pressure change in the oral cavity was recorded on a smoked paper of the rotating drum simultaneously with the movement of the operculars (Fig. 1) .

Results

The curve in the registered trace of the pressure change keeps pace with that of the operculars movement during the normal respiration. Namely an ascent was registered in the trace of the pressure change during expiration to which an ascent corresponds on the record of the opercular movement. During inspiration, where the trace of the opercular movement is downwards, a descent is recorded on the trace of the pressure change. The value of the pressure change was about 2 mm.H_2O. It is remarkable that on the course of the ascent in the trace of the pressure change a more sudden ascent from the point marked B was recorded just as in that of the opercular movement. The records are partly shown with schematic illustration (Fig. 2, 1~3).

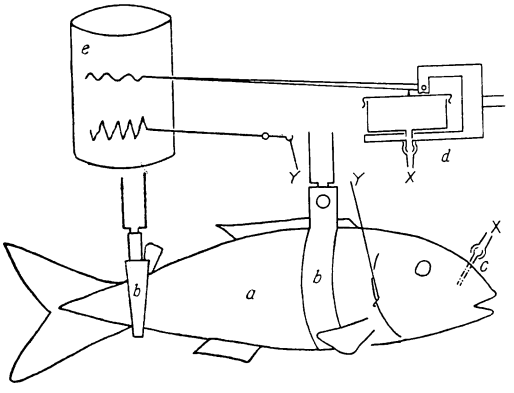

Fig. 1. Schematic illustration of the record method a : fish b : fixer c : glass tube d: Mareys tambour e : smoked paper on the rotating drum x-x : rubber tube y-y: string

The respiration is regularly interrupted through the so-called cleaning motion. This motion was found to be conveniently divided into three types in respect of the feature in the pressure change and in the opercular movement.

Type 1. On the trace of the opercular movement an ascent is alternated in the course at the point corresponding to B' and the curve falls down to the point lower than the bottom level in the

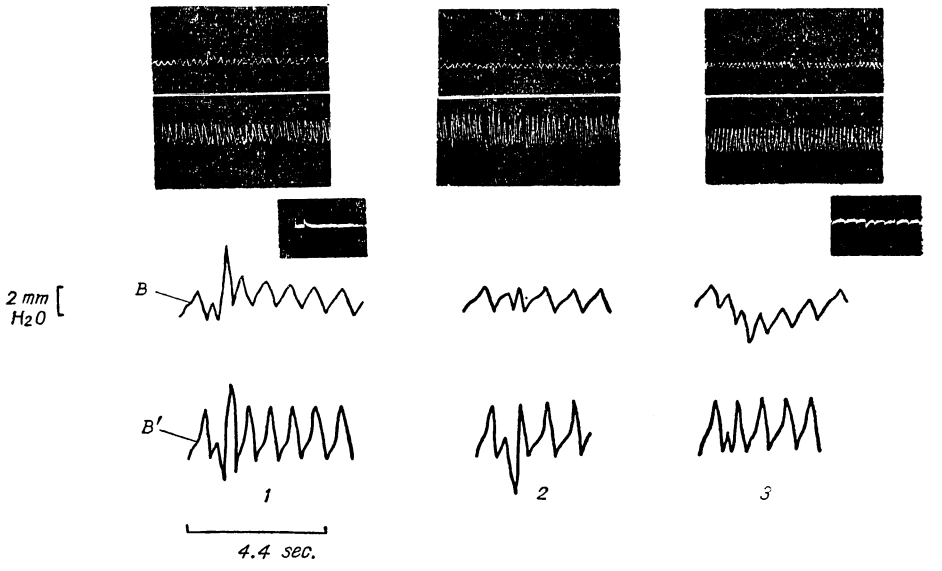

Fig. 2. The trace and schematic illustration of the pressure change caused by the so-called cleaning motion. above: the trace, middle: the scheme of the pressure change, below: the scheme of the opercular movement. 1: type 1 the pressure level was elevated. 2: type 2 unchanged. 3: type 3 lowered.

normal respiration, followed by a sudden ascent.

On the trace of the pressure change, after an ascent up to B a sudden descent is recorded, followed by a more sudden ascent up to the point higher than the peak level of the normal pressure change (Fig. 2,1). This ascent is characterized with the following gradual descent during the course of several respiratory cycles.

In the course of this movement the operculars are forced to be abducted and adducted more intensively than in that of the normal respiratory movement.

Type 2. An ascent up to B' preceeds a sudden fall down to the point lower than the bottom level and an ascent up to the peak level by the normal respiration follows in the tracing of the opercular movement.

The pressure change in this case does not exceed the peak and the bottom level by the normal respiration (Fig. 2,2).

The wide abduction of the opercular followed by an adduction of the extent of the normal respiration may not cause any remarkable change in pressure level within the oral cavity.

Type 3. Ascent and descent of the normal extent, following the ascent up to B', in the tracing of the opercular movement causes a descent in the pressure down to the point lower than the bottom level in the normal respiration. This descent recovers gradually in the course of several respiratory cycles to the normal level (Fig. 2,3).

These three types are mentioned only for convenience. Changing types from

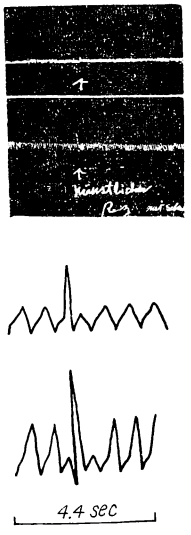

Fig. 3. The pressure change in spitreflex caused by the string flowed into the oral cavity

one of them to another were of course registered. During the course of some experiments only one type of them appeared, and that, it was never alternated to another type, though a graduate change in a long time may be possible.

The so-called cleaning motion occurs often in the case where fish is weekened or the brain of it is exposed to poisenous substances (MASUGI, 1922). In this experiment it was observed that the ascent of the pressure levels by the motion follows the less frequent occurence of cleaning motion and the descent the more frequent one. Therefore the type of the pressure change may correspond to the physiological condition of fish.

An inflow of some little solid into the oral cavity causes the spitreflex. On this reflex a sudden ascent in pressure was recorded. which was followed by an equal descent in the next inspiratory movement as shown in Fig. 3. The next expiratory movement is less powerful.

When it was darkened during an experiment a temporal descent of the pressure level occurred. A water stream artificially caused towards the mouth opening produced an ascent of the

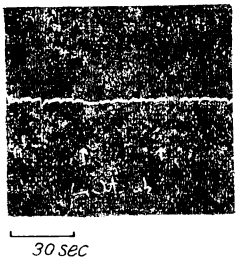

Fig. 4. The room was suddenly darkened in the course of recording, and the pressure level was temporarily lowered

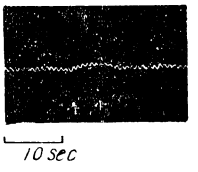

Fig. 5. Water stream caused artificially towards the mouth produced a rise in the pressure level

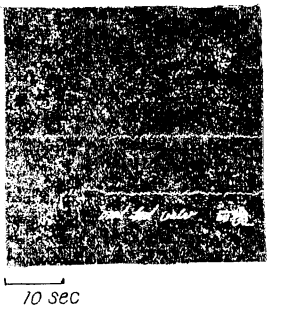

Fig. 6. The oral valves were removed below. left: before the removal, below right and above: after the removal

pressure level in the oral cavity, which gradually recovered after the cessetion of the stream (Figs. 4, 5).

In higher vertebrates the pressure within the lungs balances twice to that of the external one during one cycle of respiration. In fish it is not the case, probably since the oral and opercular valves come into play during the respiratory cycle. In the course of this experiment the valves were removed. The removal of the oral valves caused an about 50 % decrease in the value of the pressure change, and a

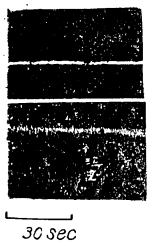

Fig. 7
The respiratory movement was reflectively inhibited through a knock on the table and the pressure within the oral cavity remained unchanged for a while

slight increase in the frequency (Fig. 6). The removal of the opercular valves however did not produce any remarkable change. Since the gills move in the rhythm of the respiration and the operculars are not so important in the ingestion of air in the loach(KOYAMA), the result above may be interpreted; the removal of opercular valves is readily compensated for, though they are probably effective in causing the waterstream for breathing in the normal specimen.

By a knock on the wall of the experimental vessel the respiratory movement was considerably slowed down and the innerpressure remains unchanged for a time near by the bottom level in the tracing (Fig. 7). It seems possible that the innerpressure does not stationarily balance with the external one during any stage of the respiration.

Discussion

The so-called cleaning motion was once called cleaning or cough reflex, since the movement of the operculars in this motion is similar to that of the spitreflex. In Europe it is called with the term "reflex" today also. MASUGI (1922) however concluded from results of his experiments that the term "reflex" is not suitable for this motion and named it cleaning motion.

In this experiment it was often recorded that the pressure level is lowered by the motion and that the change of the pressure level caused by this motion recovers gradually to the normal value. Therefore the name "cleaning" itself is not suitable for this motion.

In the spitreflex on the contrary the sudden increase of the pressure is followed by an equally sudden decrease down to the normal pressure level in the oral cavity. The name given to this motion is presumably adequate.

In the tracing of the opercular movement during the normal respiration the record of an expiration consists of the ascent up to the point B' and the next more sudden ascent. In that of the so-called cleaning motion the record is divided into two parts, the first ascent up to B' and a descent down to the normal level or much lower, and the next sharp ascent followed by a sharp descent. It seems probable that in a cycle of the normal respiration two different motions are imposed together, in the so-called cleaning motion these appear separately but in succession, being caused through unknown reason, and that the effectiveness by each of them to the pressure change within the oral cavity is different.

During the normal respiration the effects by inspiratory and expiratory movement balance each other. The volume of inflow and outflow-water is equal. The pressure level remains unchanged. But in the cleaning motion of the type 1 where the inspiratory movement following the expiratory up to the point B' is powerful, the effect by inspiratory movement overbalances that by expiratory one; more water

than as usual inflows, while the outflow through the opercular opening remains almost constant. The oral cavity is a little more expanded than as usual. Due to the elastisity of the wall of the oral cavity the pressure level is elevated. The once elevated pressure level falls only gradually down to the normal level, till the volume of water in the oral cavity becomes normal. In the type 3 where the abduction and adduction of the operculars are of the extent of the normal respiration, the pressing effect must exceed the sucking one. The oral cavity is supplied with less volume of water. The following normal respiratory movement produces negative pressure, since the elastisity of the wall probably acts rather sucking. This causes consequently a gradual ascent of the once descended curve in the tracing of the pressure change. Any way the so-called cleaning motion seems to be caused through some disturbance in the respiratory movement.

In this experiment it was noticed that during normal respiratory movement the pressure within the oral cavity does not balance stationarily with that of the outermedium to a sharp contrast with that in lungbreathers.

Summary

1. The pressure change in the oral cavity by the normal respiration was about 2 mm. H_2O.

2. The so-called cleaning motion was divided into three types according to the feature in the pressure change and operculars movement (see text).

3. The once elevated or lowered pressure level by the so-called cleaning motion recovers gradually in the course of several cycles of the following normal respiration.

4. By the spitreflex a sudden ascent and descent down to the normal level was recorded.

5. The removal of the oral valves resulted in almost 50 % decrease of the pressure change. That of the opercular valves did not produce any remarkable change.

6. From results above the following was concluded.

a) The name "cleaning" is not suitable for this motion.

b) The pressure within the oral cavity does not stationarily balance with that of the outermedium during the normal respiration.

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