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# The Readjustment of the Peripheral Lung Motor Mechanism after Bilateral Vagotomy

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# THE READJUSTMENT OF THE PERIPHERAL LUNG MOTOR MECHANISM AFTER BILATERAL VAGOTOMY

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It has been shown by Carlson and Luckhardt (1) in crucial experiments (1 to 2 hours) that destruction of the medulla or section of the vagi in the frog leads immediately to a permanent hypertonus or incomplete tetanus of the lung neuro-muscular mechanism, which makes the lung practically non-functional and useless as a respiratory organ. The present work however, was undertaken with the idea of ascertaining whether this hypertonic condition observed by these authors is permanent or temporary.

The older literature dealing with the respiratory movements of the frog, which it is not necessary to go into here, is more or less conflicting and inadequate in itself to explain the true lung reaction resulting from destruction of the medulla or section of the vagi and needs re-investigation, especially in view of the recent results of Carlson and Luckhardt in acute experiments.

The anatomy of the frog's lung is well known, it being a paired muscular sac having numerous muscular septa on the interior surface dividing it into small spaces or alveoli. The septa extend only a few millimeters from the lung wall, so that the larger part of the lung cavity is a large single air space. There are no bronchi and no true trachea, the tracheal sac having essentially the same structure as the rest of the lung and probably carrying the same respiratory function. The entire wall of the lungs is covered with smooth musculature which extends into the smallest septa on the inner surface, while more or less definite external muscular strands follow the course of the main pulmonary blood vessels on the lung surface. The lung musculature is so arranged that contraction, even of the septal musculature, will reduce the size of the lung cavity, or raise the intrapulmonary pressure in of the septal musculature would be analogous to that of the bron- case the air in the lung is not free to escape. Hence, the action chial constrictor muscle of the mammalian lung.

According to the histological studies of Arnold (2), Smirnow (3), Cuccate (4) and Wolff (5) there are numerous ganglia, as well as isolated ganglion cells (multipolar and bipolar) along the course of the main vago-sympathetic nerve trunks on the surface of the lung, the nerve fibers of which are both medullated and non-medullated. In addition, there is a plexus of fine non-medullated nerve fibers which surrounds the strands of the lung musculature. These nerve plexuses and ganglion cells are most abundant at the base of the lung and Arnold points out that these are histologically identical with those of the frog's heart. They are also probably identical, both as to histology and function, with the ganglionic plexuses (Auerbach) in the wall of the gut, especially as the lung is a diverticulum from the foregut (esophagus), therefore, it would be reasonable to look for a gradual physiological readjustment of the peripheral lung motor mechanism similar to that which gradually occurs in the case of the gastro-neuromuscular mechanism of the bullfrog (6) after section of the vagi or the splanchnic nerves.

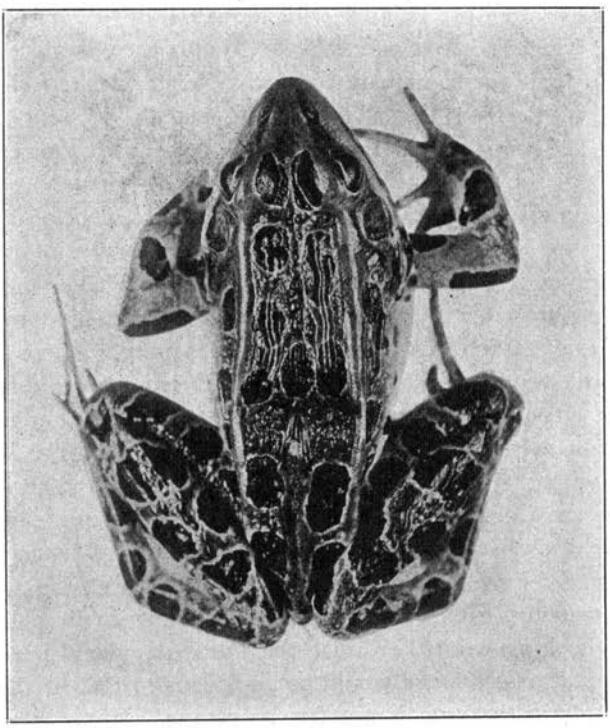

Fig. 31a. Frog 10, *control,* showing the normal contour of the flanks. (After 6 weeks as a control animal bilateral vagotomy was performed. It then lived 247 days and was the only animal in which complete physiological readjustment of the peripheral lung motor mechanism occurred.)

In the frog, the external respiratory acts consisting of buccal movements, closing of nares, expiration and inspiration or swallowing air, occur in a coördinated and orderly sequence, the buccal or passive movements proceeding rhythmically between the swallowing acts, so that there are several buccal movements between each swallowing act. This is the usual type of buccal movements exhibited in the frog although in exceptional cases there may be at times in certain animals a perfect synchrony between these movements and the actual swallowing of air (inspiration). It should be emphasized here, that the external respiratory mechanism of the amphibians differs from that of all other air-breathing animals in that the air enters the lungs under positive pressure due to the act of swallowing, therefore, this might indicate possibly that the respiratory center in the medulla of this animal is anatomically and physiologically identical with the center for deglutition.

The buccal or passive movements are distinct from the quick respiratory movements of the flanks, the latter being due to the act of inspiration or the swallowing of air which is preceded by the opening of the glottis and the escape of some air into the buccal cavity. This results first in a diminution in the size of the lungs with a corresponding falling in of the flanks which is then quickly compensated for by a distension of the lungs which in most animals show a periodicity similar to the Cheyne-Stokes type of breathing in mammals.

The experiments forming the basis of this report were made exclusively on the common laboratory frog (*Rana pipiens*). Healthy, vigorous animals were selected in pairs, one of which was kept as a control, while in the other, one or both vagi were sectioned in the region of the neck after anaesthesia. The delicate technique for this operation in this species of frog consists in making two oblique incisions through the skin on either side of the median line, ventral, about ½ cm. distant and close to the anterior tips of the shoulders as represented by a line drawn from this point laterally about 1 cm. in length to a point slightly posterior and just internal to the articulation of the superior and inferior maxillary bones on either side. These two incisions expose the cervical fascia on either side at its attachment along the anterior scapulo-clavicular borders. Few blood vessels are present and if the fascia is carefully separated no hemorrhage results. The fascial separation beyond this region now becomes very easy until the thin sheet of prevertebral fascia is reached which is

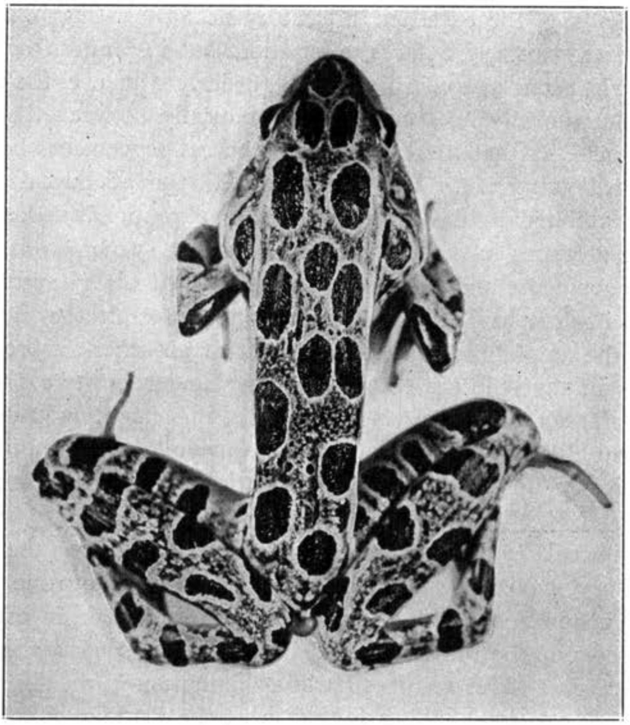

Fig. 31b. Frog 10, 9 days after bilateral vagotomy, showing complete absence of the normal contour of the flanks. Note the straight body lines as compared to the control in figure 31a.

about on a line of the transverse processes passing obliquely downward and inward from the base of the skull and extending into the thorax. This latter sheet of fascial membrane is now pierced, which exposes the levator anguli scapulae muscle, over the anterior border of which courses the vagus nerve and the internal jugular (Vena jugularis) and musculo-cutaneous (Vena musculo-cutanea) veins. The incision is held open by the spring of a small pair of ordinary forceps (preferably curved points) and then by means of a small pair of mouse-toothed or eye forceps (iris forceps) the nerve is carefully separated from the adjoining veins to which it is bound by connected tissue. This is best accomplished by freeing the nerve either between the two veins mentioned or just lateral to the internal jugular vein at the anterior border of the levator anguli scapulae where it crosses and sectioning the nerve just below the origin of the recurrent laryngeal branch. Section of the nerves at this point destroys not only the pulmonary branches to the lungs but also the cardiac and gastric branches destined for the heart and stomach. In unilateral section only the right or left vagus nerve was cut. In the case of bilateral vagotomy, both vagi were always sectioned at one operation and the skin incisions closed with four sutures. After recovery of the animals, direct observations were made on the visible changes in the contour of the flanks and the external respiratory movements and compared with that of the normal or control animal.

The animals were kept under observation for periods of several weeks and even months in many cases. During this time they were kept in a large vivarium which was divided into small compartments in which the animals were kept in pairs (control and vagotomized). This was provided with running water and the animals in all the later experiments were fed on caterpillars and earthworms in order to keep them in first class condition, for any depression in the animals might defeat the object of the experiment. To further control any possibility of depression resulting from the confinement of the animals, the vagi were sectioned in many of the control animals, five to eight weeks after the cutting of the nerves in the first animal but these latter or control animals always reacted in exactly the same manner as the former. Finally, all the animals at the close of the respective experiments were autopsied and the condition of the lungs and other visceral organs observed.

Since the results of this study have been published in full in the American Journal of Physiology (November, 1921), Vol. LVIII, No. 1, it is necessary here only to give a resumé of some of the more important conclusions.

Bilateral vagotomy in the frog (*Rana pipiens*) destroys the inhibitory control over the peripheral lung automatism leaving it free to exert its full influence on the lungs without any check, hence the lungs contract and pass into a state of hypertonus or lung tetanus to such a degree as to nullify their function. The normal contour of the flanks in these animals disappears and the body line becomes straight or even curved in.

In unilateral section of the vago-sympathetic nerve there is loss of the inhibitory control over the peripheral lung automatism on the side of the section only, the opposite lung being unaffected, thus showing that the nerve action is unilateral.

In both unilateral and bilateral section of the vago-sympathetic nerves there is a gradual physiological readjustment of the peripheral lung motor mechanism which usually starts from 12 to

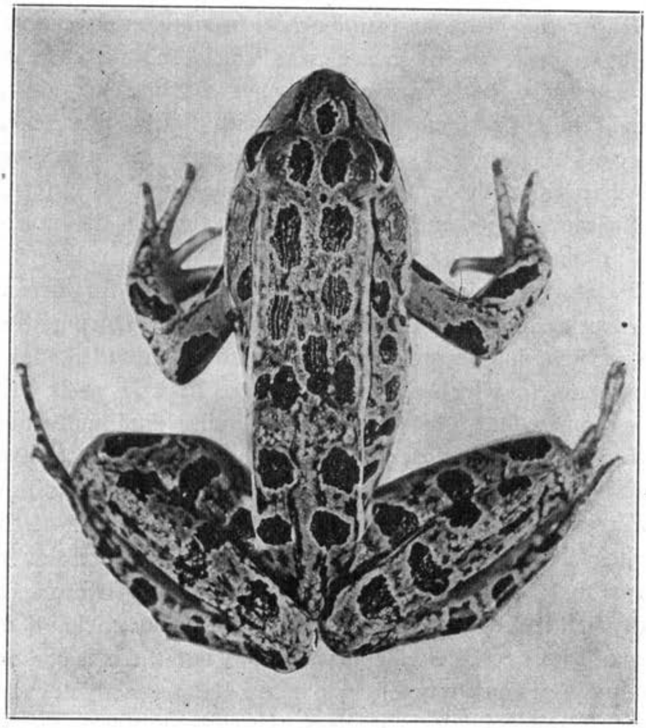

Fig. 31c. Frog 30, 7 days after unilateral section of the left vago-sympathetic nerve, showing total absence of the normal contour of the flank on the side of the nerve section only. Compare with the normal contour of the flank of the right side.

21 days after the nerve section when the lung begins to be distended by swallowed air, pushing out the flanks and finally forming "olive-shaped" prominences. This readjustment was partial in all the animals with the exception of one, which lived for an extended period of a little over 8 months, the complete physiological readjustment occurring at the end of about 7½ months. In other animals living for periods of from 2 to 5 months, those of 5 months standing always showed a greater degree of physiological readjustment than those of less duration.

In recent bilateral vagotomized animals up to periods of from 2 to 3 weeks air is found more constantly and usually in greater amounts in the stomach and intestine than in similarly operated animals of longer standing. This indicates that the air is forced into the stomach by the act of swallowing because of the persistently constricted lungs aided probably by a hypotonic stomach, at least in the early stages.

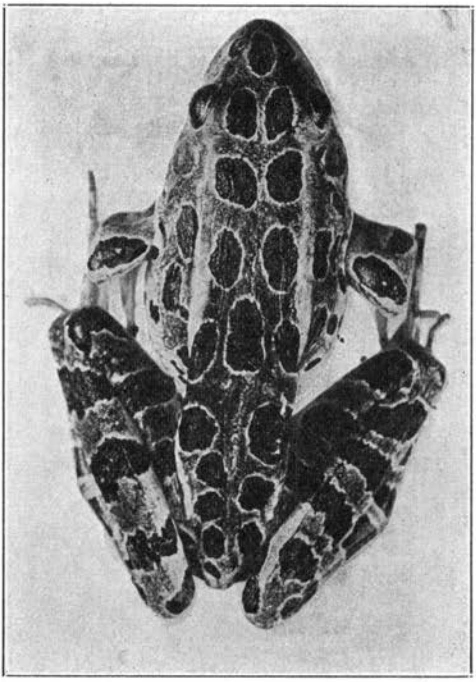

Fig. 31d. Same animal as in figure 31b, 32 days after bilateral vagotomy, showing a partial physiological readjustment of the peripheral lung motor mechanism. Note the "olive-shaped" prominences.

All the autopsy findings confirmed the above results.

Bilateral vagotomy has little or no effect on the buccal movements, whereas the actual respiratory movements (opening of glottis and swallowing of air into lungs) are temporarily abolished, but these movements gradually return with the physiological readjustment of the peripheral lung motor mechanism.

The lung readjustment in these long time experiments is not due to a gradual weakening of the animals from age and starvation since animals when fed and kept in close confinement react in a similar manner after unilateral or bilateral vagotomy as do normal animals which have not been so kept. Furthermore, the failure of the vagotomized lungs to contract down to practically a solid mass on death or destruction of the medulla in these experiments is evidence that this readjustment is not due to a vagus regeneration. It may be implied, therefore, that this physiological readjustment of the vagotomized lung is brought about through some special activity of its peripheral neuro-muscular mechanism.

## REFERENCES

(1) Carlson and Luckhardt: Am. Jour. Physiol., 1920, LIV, 55.
(2) Arnold: Virchow's Arch., 1863, XXVIII, 433.
(3) Smirnow: Anat. Anzeiger, 1888, III, 258.
(4) Cuccate: Int. Monatschr. f. Anat. u. Physiol., 1888, V, 194.
(5) Wolff: Arch. f. Anat., 1902, 179.
(6) Patterson: Am. Jour. Physiol., 1920, LIV, 153.

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