CONTINUOUS RESPIRATION WITHOUT RESPIRATORY MOVEMENTS.[1]

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The object of the function of respiration is to supply the animal with oxygen and to remove carbon dioxide. To attain this object the vertebrates are provided with a complicated mechanism of which the respiratory movements are an essential feature. The respiration appears as a continuous chain of rhythmically recurring cycles, each cycle consisting of two antagonistic movements, one which carries air into the body and the other which assists its removal from the body. When the muscular activity of the body is eliminated by one cause or other and the exchange of the gases is carried on by so-called artificial respiration, again the respiration is rhythmically discontinuous and each cycle is composed of the two antagonistic movements: the inflow of air is carried on rhythmically by some external mechanism, while the return of the air is accomplished during the intermission by the elastic forces of the body. The rhythmic antagonistic movements seem thus to be inseparable from the function of respiration.

In studying recently the nature of the mechanism of the respiration in the presence of a double pneumothorax, while the animal is breathing compressed air by the Brauer method of overpressure, we discovered the fact that under certain conditions respiration can be carried on by continuous inflation of the lungs, and without any normal or artificial rhythmical respiratory movements whatever. This observation was verified by many experiments and we will describe here briefly the essential features of the experiment.

A longitudinal slit is made in the trachea of an anesthetized dog or rabbit and a glass tube introduced down to the tracheal bifurca-

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tion. The protruding end of the tube is then connected with a pressure bottle by means of a T-tube, the opening of the free branch of which is regulated by a screw clamp. The air which streams from the bottle under pressure partly escapes through the free branch of the T-tube and partly enters the trachea and reaches the bifurcation from which it returns through the space between tracheal wall and tube and escapes through the slit in the trachea and through mouth and nose. It is essential that the tube should fill out two-thirds of the lumen of the trachea, that the slit in the trachea be not too short and that the pressure of the air which enters the T-tube should amount to about fifteen to twenty millimeters of mercury. The pressure within the trachea is of course much lower than that. In the connection between the trachea and the pressure bottle are interpolated a manometer, an ether bottle and a bottle with Ringer's solution to keep the mucous membrane of the trachea moist. The essential point of the arrangement is that air is reaching the bifurcation under pressure and returns through another path than that through which it entered. When the air is thus circulating through the trachea the diaphragm descends, the thorax becomes moderately distended and the respiration mostly becomes very slow. The heart beats also frequently become dangerously slow. This danger, however, is easily obviated by an intravenous injection of one milligram of atropin; in a few seconds the pulse becomes frequent and remains so for many hours. The animal may receive now an intravenous injection of curare sufficient to completely abolish any spontaneous or reflex movements; its life is as safe as under regular artificial respiration. When the anterior thoracic wall is removed, the distended lungs are seen to be immobile while the heart continues to beat with a regular rhythm. If the above described arrangement is carried out properly the lungs retain their pink color, the heart continues to beat regularly and efficiently for many hours and the blood-pressure shows but little variation.

We have observed animals four hours and longer under these normal conditions. If the glass tube within the trachea is a little too wide or too narrow in relation to the lumen of the trachea the lungs acquire easily a slightly cyanotic appearance. But then a disconnection of the tube from the pressure bottle for two seconds, which means a momentary collapse of the lungs, restores immediately the pink color of the lungs and a repetition of this procedure once every three or four minutes is sufficient to maintain the life of the animal in a satisfactory fashion for many hours, although under these circumstances the blood-pressure is subject to frequent variations.

In another method, the tube which conveys the air to the lungs is short—a regular tracheotomy tube—and is tied in firmly in the upper part of the trachea, while another narrower tube is inserted into the trachea through a narrow opening made at a lower place. This tube reaches the bifurcation and serves for the removal of the air. This method also was found to do satisfactory service. In a third method, a long O'Dwyer tube, bent at right angles, was introduced through the mouth and inserted into the larynx. Through this tube a catheter was pushed into the trachea until it reached the bifurcation. Both tubes were then connected with the pressure bottle in such a manner as to let the air enter through the O'Dwyer tube and escape through the catheter. This arrangement, however, has failed as yet to give uniform results. The method, however, is surely capable of improvement and it is probable that it will finally give satisfactory results.

If the air is made to enter the lungs through a short tracheal tube firmly tied into the trachea, the curarized animals die in a very short time from asphyxia. With this method, the spontaneous respirations of the animals are apparently indispensable for the maintenance of their life. The result is not perceptibly better even if the firmly tied-in tube reaches the bifurcation. The difficulty of this method consists mainly in the fact that the removal of the carbon dioxide has to take place against the stream of the air within the tube; while in our method the removal of the carbon dioxide is rather assisted by this stream of air.

The following three points are the essential factors in the success of our method: (1) The lungs are kept in continuous inspiratory state of distension which facilitates the exchange of the gases. (2) The fresh air reaches the lowest part of the trachea. (3) The air escapes by another path (although also through the trachea) than by the one it enters. Under these conditions the supply of oxygen and removal of carbon dioxide take place apparently in physiological fashion without the aid of any rhythmic antagonistic movements.

Besides the direct physiological bearing of our experiments on the function of respiration the method is destined to be of methodical service in other physiological investigations, for instance in the study of the heart actions where the movement of the lungs is a disturbing factor. This method might in a certain way offer some advantages over the known methods of Langendorff and of Bock-Hering. Furthermore the method promises to be of practical service in various directions. We shall not omit to refer to two statements in the literature which can be considered as forerunners of our method. In the first place, there is the statement[2] that Hook in 1667 maintained the life of a dog for an hour by continuous inflation of the lungs previously punctured at various places. In the second place, we have to mention Nagel's[3] communication according to which the life of curarized pigeons were maintained by sending a continuous stream of air through the humerus which in birds is connected with the air sacs. In this case the air escaped through the trachea. In both instances the air escaped through the paths opposite to those through which it entered. In our method the air enters and escapes through the trachea, although through the separate paths within it.

[2] Rosenthal, Hermann's Handbuch der Physiologie, 1882, iv, 238.

[3] Nagel, *Centralbl. f. Physiol.*, 1900, xiv, 238.