

THE RELATION OF OXYGEN TENSION TO OXYGEN CONSUMPTION IN THE INSECTS AND THE CRAYFISH

WM. A. Hiestand, Purdue University

It has been shown by many workers that among the higher animals oxygen consumption is independent of oxygen tension over a wide range. This is especially true of the warm-blooded forms and of those whose blood contains respiratory pigments. Among the lower organisms (as is true of the Starfish) oxygen consumption may be dependent upon oxygen tension, that is to say, oxygen consumption grows less as the oxygen tension of the surrounding medium diminishes. This condition exists in fewer cases than an independence of oxygen tension.

With the insects practically no work has been done to determine the degree of dependence upon oxygen tensions. Two papers have been published in Europe in relation to this subject. Both investigators used the same species of insects, the meal-worm (*Tenebrio*), in different stages of its metamorphosis. This insect which is an air-breather, a holopneustic form, was found to be able to consume oxygen at a uniform rate in tensions varying from three to 97 percent oxygen. No other references to insects have been found by the writer.

Using the large Florida roach, (*Periplaneta australasiae*), the writer has been able to produce results somewhat comparable to the aforementioned investigations. However, not enough data have been collected to verify any definite conclusions in regard to the respiration of this insect.

The writer has been more interested in the respiration of aquatic insects. These forms offer varying possibilities in regard to oxygen consumption. In the first place the oxygen of the aquatic medium is not as easily available as oxygen in the air. Secondly, the respiratory mechanisms of aquatic insects are apparently less efficient than those of air-breathing ones. Lastly, the oxygen concentration of water varies greatly from time to time. Hence, it is important as well as interesting to ascertain to what extent the respiration of true water breathing insects is influenced by varying oxygen tensions. Only insects which received their oxygen from the water in a dissolved condition were used. Surface breathers were eliminated as they are not true aquatic forms.

Two forms of insects, the nymphs of the dragon-fly, (*Nasiaeschna penthacantha*) and the larvae of the caddis-fly, (*Limnaphilus rhombiscus*) were selected for the following investigations, and also the common crayfish, (*Cambarus virilis*) was used as a comparative arthropod known to possess a respiratory pigment. It should be stated at this point that the existence of respiratory pigments in the insects employed has never been demonstrated. In all probability some form of pigment exists as an aid to the respiratory mechanisms of these animals as may be seen from the results. We should expect to find with animals devoid of pigments quite a distinct correlation of oxygen consumption with available oxygen of the environment.

The method employed consisted of measuring the oxygen tension of the water containing the insects at regular intervals and recording the results graphically in order to show the relation of oxygen consumption to the tension of oxygen. The animals were kept in a closed container of distilled water from which small (10 cc.) samples were withdrawn at regular intervals for oxygen analyses by a micro-Winkler method. No outside air was permitted to come in contact with the

water during the procedure. Analyses were also made of carbon dioxide before and after each experiment. The methods were carefully tested and checked. All factors other than oxygen tension were eliminated.

Results of the experiments with dragon-fly nymphs: The nymphs were able to consume oxygen at a practically uniform rate from the water containing oxygen at equilibrium with air down to less than one-half the normal saturation. At this latter point the oxygen consumption rapidly diminished and practically ceased. This result indicates that these insects can adjust their oxygen consumption in such a way that they are virtually independent of oxygen tensions of water of normal to one-half normal saturation with air.

In water containing free carbon dioxide the nymphs showed the ability to continue their oxygen consumption until much lower levels were reached. In fact oxygen consumption continued until the water contained only about one-fifth the original oxygen percentage. Evidently free carbon-dioxide in the surrounding medium stimulates the respiration of these insects and enables them to withstand tensions lower than otherwise. Also the rate at which oxygen is consumed is greater than when no free carbon-dioxide is present.

By increasing the hydrogen-ion concentration of the water the same effect was produced as with free carbon-dioxide. Thus a lowered pH acts as a respiratory stimulant as well as carbon dioxide. It should be mentioned at this time that the combined effects of high carbon-dioxide content and a low pH do not have any augmentation effect greater than that produced by either alone.

Results of the experiments with caddis-fly larvae: Caddis-worms showed the ability to consume oxygen at a very uniform rate until the oxygen concentration was reduced to about one-fourth normal. At this point the consumption practically ceased.

If water containing a high oxygen content was employed (produced by shaking distilled water with pure oxygen) the rate of oxygen consumption was not altered, the animals continuing to use it at the same rate in spite of the abundance of it.

If the oxygen tension was diminished too rapidly the rate of consumption showed an apparent dependence upon the tension. It was later proved that this condition resulted from a lack of time for the insects to accommodate themselves to the rapidly diminishing tensions. In other words the animals formed an oxygen debt as the oxygen grew less which continued until the point had been reached at which oxygen consumption ceased entirely.

Thus it can be said that normally these aquatic insects are independent of oxygen tensions of the water to a low level at which point consumption practically ceases. They have the ability to regulate their respiration to compensate for the diminished amount of oxygen if given a long enough time to do so.

These results would seem to indicate the presence of a regulatory mechanism which enables the insects to adjust their rate of oxygen consumption to fit the varying conditions of their environment. It seems highly probable that they possess respiratory pigments to aid in compensating for a deficiency in oxygen.

Results from experiments with the crayfish: It was found that the oxygen consumption of the crayfish agrees favorably with that of the insects. If allowed sufficient time for adapting themselves these animals can regulate their oxygen consumption over a range of all tensions above one-fourth that of the normal equilibrium of water and air. If the oxygen tension diminishes too rapidly they also form an oxygen debt due to the fact that they do not have sufficient time to effect an adjustment.