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Biology Essay: Describe the Structural and Physiological Adaptations Shown by Invertebrates to Varying Oxygen Concentrations.

For aquatic animals, changes in oxygen concentration are particularly important because many aquatic animals cannot survive when oxygen concentrations dip below a certain level. Oxygen concentrations also determine the solubility of several important substances, notably phosphate, iron, and manganese.

One problem faced is that the oxygen concentration in water is a great deal less than that of air, as oxygen is soluble in water only to a limited extent, so the respiratory gases needed are much less available in water than they are in air. Also, oxygen availability is temperature dependent. The solubility of any gas in water depends on the temperature of medium: the warmer the medium, the lower the concentration of gas which can be dissolved in it:

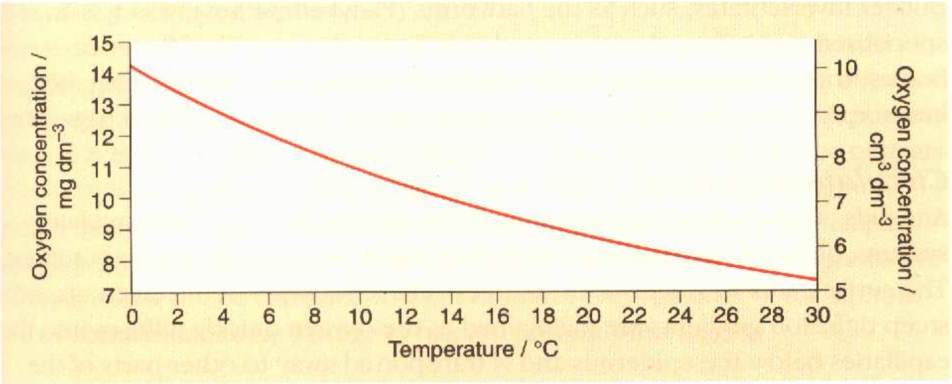

Figure 3.7 The oxygen content of water decreases as water temperature increases

Water viscosity is also much greater than air viscosity. Viscosity is the tendency of the fluid to resist flow, and is important when it comes to respiration, because respiration requires the movement of fluid over a respiratory surface. The more viscose the fluid, the more difficult that movement becomes. Water viscosity makes it difficult to ventilate a respiratory surface sufficiently to get enough oxygen from the low concentration contained within it. In some cases, this problem is overcome by providing a larger surface area over which the oxygen can be dissolved. For example, oxygen may be obtained by diffusion over the entire body surface.

Essentially, the problems faced by invertebrates when obtaining oxygen from water are solved by five methods of respiration:

1. Passive diffusion
   This is a reliance on movement of respiratory gases by diffusion across the body surface of the invertebrate. It is only effective at high surface area to volume ratios, so where the concentration of oxygen inside the organism is lower than that of the surrounding water, a concentration gradient is formed, allowing diffusion of the oxygen. This means on the whole it is only possible in invertebrates which are small or long and thin, and the rate of diffusion through the organism decreases as the bulk increases. This method can be found most frequently in the larvae of the family Chironomidae which are long, thin, non-biting midges, or in larvae of the Simuliidae, which are the black flies, and in some of the mites (arachnids), such as those belonging to the group Hydracarina. It is also used by some of the smallest aquatic invertebrates, such as the protoctistans and cnidarians.

2. Biological gills
   Some of the larger invertebrates have developed structures which are specialised for respiratory structure in water. Amongst the insects, biological gills tend to be concentrations of tracheae just

below the surface of the thin walled cuticle. Amongst the insects which live in freshwater these biological gills are found containing concentrations of tracheae in various places, with these opening to the outside by means of spiracles, located on the thorax and abdomen. For example, these tracheae can be found at the end of the abdomen (caudal gills), along the abdomen itself (abdominal gills), or on the thorax (thoracic gills). Occasionally there is the development of secondary gills. For example, the common river limpet Ancylus has a newly developed gill located within a flooded mantle cavity.

3. Breathing tubes or siphons
   These are essentially tubes which enable an aquatic invertebrate to continue to rely on atmospheric gas. It consists of a breathing tube that leads from the invertebrate respiratory structure to the surface of the water. These are used primarily by aquatic insects living in still water. The insect is able to rise up to the surface of the water where it can obtain oxygen through spiracles. Such adaptations can be found in the Culicidae, which include the mosquitoes and gnats in their larval stages. They have breathing tubes on the end of the abdomen, which are brought to the surface of the water. Here they are quite short and the larva hangs below the water surface. In the drone fly larvae (colloquially known as rat-tailed maggots) the breathing tube is quite long, and may be several times the length of animal's body. This enables them to live on the bottom of freshwater habitat and yet breathe oxygen.

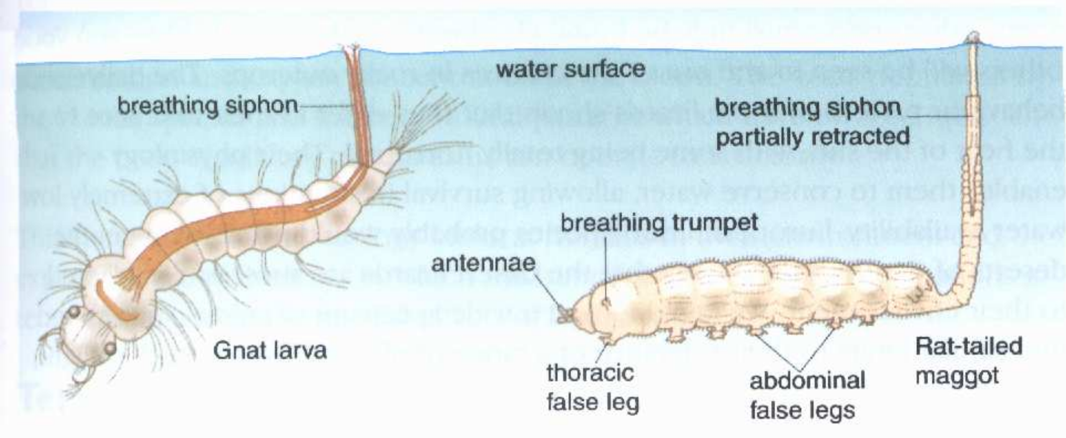

Figure 3.10 Different adaptations in these larvae allow for gas exchange

   There are however two disadvantages: they are limited in the depth to which they can live by the length of the tube, so live in places which are relatively shallow and cannot easily cope with fast flowing water, so are limited to static or slow moving environments.

4. Air store (aqualung)
   This is where an invertebrate carries with it an air store from which it breathes which is renewed from time to time. The inner surface of the mantle cavity functions as a lung, and the insect must return to the surface to replenish the air supply. The frequency with which they are required to replenish the supply depends on the oxygen levels in the water. Quite a wide range of invertebrates use this devise, including the common pond snail, Limnaea, which is a genus of aquatic gastropod where the mantle cavity is used as an air store. From time to time the snail has to return to the surface to renew the gas in the store.

   The first disadvantage of using an air store is buoyancy. It means that an animal carrying the air store has to swim or cling on to something to stay below the surface of the water. Another disadvantage is the need to return to the surface of the water to replenish the air store. In many cases this leaves invertebrates vulnerable to its various predators.

5. Use of bubbles
   Also, there are the insects that might be termed 'bubble breathers'. One example is the water beetle Dytiscus, which takes on a gas supply in the form of an air bubble under their fore wing, next to the

spiracles before they submerge, which acts as a gill. Tracheal gas exchange continues after the beetle submerges and anchors itself beneath the surface. As the beetle takes in oxygen from the bubble, the partial pressure of oxygen inside the bubble falls below that in the water; causing oxygen to diffuse from the water into the bubble to replace that consumed. The carbon dioxide produced by the beetle diffuses through its tracheal system into the bubble and from there into the water. Due to the partial pressure of nitrogen in the bubble rising as oxygen is removed, the nitrogen diffuses out to the water, causing the bubble to shrink. This means the supply must be replenished by another trip to the surface. The water boatman also transports an air bubble down into the water for gaseous exchange. It traps a bubble of air among the hairs at the base of the abdomen. When the air has been used up, the inset simply returns to the surface for a fresh supply of air.

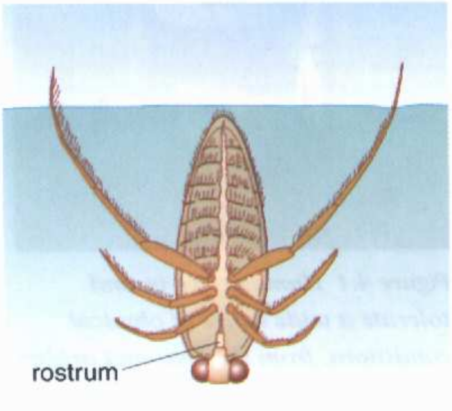

Figure 3.11 The water boatman (Notonecta glauca) *obtains oxygen by trapping bubbles of air under its abdomen*

Reference for this essay taken from the text book ‘Exchange and Transport, Energy and Ecosystems’, and from the following web sites: www.aber.ac.uk, and www.britannica.com