Counter current exchange

Counter current exchange is the mechanism by which some property of a fluid, such as heat or a chemical substance, is transferred from one fluid across a semi-permeable membrane or thermally conductive material to another fluid flowing in the opposite direction. The general requirements for counter current exchange are (1) that two fluids flow in close proximity to each other and (2) that the fluids flow in opposite directions. The purpose of counter current exchange is to maintain a concentration gradient between the two fluids in order to maximize movement from one fluid to the other. The opposite of counter current exchange occurs in concurrent exchange when two fluids flow in the same direction.

Example of counter current exchange: fish gills
The principle of counter current exchange can be illustrated using fish gills. In the gills, oxygen diffuses from an area of high concentration, the water, into an area of lower concentration, the fish's bloodstream. First consider what would happen under same or concurrent exchange. If oxygen-rich water and oxygen-deficient blood flow in the same direction, diffusion occurs into the bloodstream until equilibrium is reached. Thus, the maximum amount of oxygen that can enter the blood at any given time is only 50% of the total oxygen. On the other hand, if oxygen-rich water and oxygen-deficient blood flow in opposite directions, oxygen diffusion is continuous. This is because even though the oxygen concentration may decrease, the amount of oxygen in the water is always slightly greater than that in the blood, allowing diffusion to continue, and equilibrium to be avoided. In this case, the maximum amount of oxygen that can enter the blood is 90%, much greater than the amount which entered via concurrent exchange.

Other uses of counter current exchange
Counter current exchange systems are found in various biological systems performing a wide range of functions and are a major concept in chemical engineering and manufacturing.

Counter current heat exchange: heat conservation
The extremities of many aquatic animals, such as the flippers of whales and the legs of some birds, contain a counter current heat exchange system to minimize heat loss to the surroundings. Heat exchange occurs between blood vessels flowing in close proximity and in opposite directions. Warm arterial blood originating from the body transfers heat to the colder venous blood returning from the extremities of the animal, thereby warming the veins and minimizing heat loss (see Counter current exchange: heat conservation).

Counter current heat exchange: water conservation
Another example of a counter current exchange occurs in the nose of desert rodents, such as kangaroo rats. In the nose, a single passageway facilitates inhalation of dry, cool air and exhalation of warm, moist air. In this case, the separation of the two fluids (inhaled and exhaled air) is not spatial as in the fish example, but rather it is a temporal. Because kangaroo rats live in a dry, hot environment, the most important function of the exchange system is to decrease water loss during exhalation (see Adaptations to deserts: counter current exchange in nasal passages).

Counter current multiplier: kidneys

A counter current multiplier system exists in the loop of Henle of the kidneys. Unlike the counter current exchange systems where movement is passive, a counter current multiplier requires an input of energy and specific transport proteins to transfer ions and create a concentration gradient. It is this type of system which is responsible for producing concentrated urine (see "Counter current multiplier in kidneys").

Further Reading

- Campbell, N.A., J.B. Reece, and L.G. Mitchell. 2006. *Biology*. Addison Wesley Longman, Inc. Menlo Park, CA. ISBN: 080537146X
- Marine Biology Learning Center. A quick course in ichthyology .
- Raven, P.H., G.B. Johnson, J.B. Losos, K.A. Mason, and S.R. Singer. 2008. *Biology*, 8th edition. McGraw Hill, New York, NY. ISBN: 0073227390
- Schmidt-Nielson, K. 2003. How animals work. Cambridge University Press, Cambridge. ISBN: 0521096928