# Section 2: Types of Circulatory Systems

Circulatory systems in invertebrates exhibit remarkable diversity, tailored to the specific physiological demands and environmental contexts of the organisms. These systems are classified into four main types: **no circulatory system**, **open circulatory systems**, **closed circulatory systems**, and the **water vascular system**. Each system demonstrates unique adaptations that ensure the transport of nutrients, gases, hormones, and waste products necessary for survival.

**No Circulatory System**

Organisms without circulatory systems rely on diffusion or other passive processes to move substances across their bodies. This arrangement is primarily found in smaller, simpler organisms, where the distance between cells and their environment is minimal. Diffusion occurs as substances naturally move from areas of high concentration to areas of low concentration, enabling the exchange of oxygen, nutrients, and waste products.

To overcome the limitations of diffusion, these organisms exhibit structural adaptations that maximize surface area and minimize the distance for diffusion. For example, **sponges (Porifera)** use water flow generated by specialized cells called choanocytes. These cells beat their flagella to create currents, drawing water through pores in the sponge’s body. As water moves through internal canals, it delivers oxygen and nutrients directly to cells before being expelled through an opening called the osculum. Similarly, **flatworms (Platyhelminthes)** rely on their flattened body shape to keep all cells close to the external environment. Their gastrovascular cavity extends throughout their bodies, distributing nutrients absorbed from food while also expelling waste.

Other groups, such as **nematodes** and **rotifers**, use their small size and thin body walls to facilitate diffusion. The lack of circulatory systems in these organisms imposes certain constraints: they are generally limited to small sizes, simple body plans, and low metabolic rates. However, for their ecological niches—such as interstitial spaces in sediments or parasitic lifestyles—this simplicity is sufficient.

**Phyla with No Circulatory System**: Porifera, Cnidaria, Platyhelminthes, Nematoda, Rotifera, Bryozoa.

**Open Circulatory Systems**

Open circulatory systems represent a more advanced adaptation, combining a heart and vessels with a body cavity known as the **haemocoel**. In these systems, a transport fluid called **hemolymph** flows freely around internal organs, bathing tissues directly. The movement of hemolymph is driven by the contraction of a heart, which pumps the fluid into short vessels that open into the haemocoel. As hemolymph spreads through the cavity, it facilitates the exchange of nutrients, hormones, and waste products with surrounding tissues.

A key feature of open circulatory systems is the return of hemolymph to the heart through **ostia**, valved openings that ensure unidirectional flow. Despite this organization, hemolymph is not confined to vessels, and its direct contact with tissues results in less precise delivery compared to closed systems. The low pressure at which these systems operate makes them energetically efficient, but it limits the speed and efficiency of substance transport, particularly for oxygen.

While open systems are less effective for gas exchange, they are sufficient for organisms with low metabolic demands or supplementary respiratory structures. For example, insects rely on their **tracheal system**, a network of air-filled tubes, to deliver oxygen directly to tissues, leaving the open circulatory system responsible for transporting nutrients and waste. This division of labor allows open systems to support relatively large and complex organisms without the high energetic cost of a closed system.

**Phyla with Open Circulatory System**: Arthropoda, Mollusca (excluding cephalopods).

**Closed Circulatory Systems**

Closed circulatory systems are the most efficient means of internal transport, characterized by blood confined within a network of vessels. In these systems, the heart pumps blood into **arteries**, which branch into smaller **capillaries** that permeate tissues. Within capillaries, nutrients, gases, and waste products are exchanged with cells before the blood returns to the heart via **veins**.

The confinement of blood within vessels allows closed systems to operate at higher pressures, enabling rapid and targeted delivery of oxygen and nutrients to tissues. This precision is essential for organisms with high metabolic demands or large body sizes. Valves within the heart and veins ensure unidirectional flow, preventing backflow and maintaining circulation efficiency.

An important feature of closed systems is their ability to support specialized structures, such as **auxiliary hearts** in cephalopods. These branchial hearts pump blood through the gills for oxygen exchange, while the systemic heart circulates oxygenated blood to the rest of the body. This division of labor allows cephalopods, such as squids and octopuses, to sustain active predatory lifestyles.

The complexity and efficiency of closed systems make them suitable for a wide range of organisms, including annelids, cephalopods, and vertebrates. For instance, in humans and other mammals, the four-chambered heart separates oxygenated and deoxygenated blood, optimizing the system for endothermic (warm-blooded) metabolism.

**Phyla with Closed Circulatory System**: Annelida, Cephalopoda, Chordata, Nemertea.

**Water Vascular System**

The water vascular system is a unique hydraulic network found exclusively in **echinoderms**, such as sea stars and sea urchins. This system integrates locomotion, feeding, and limited nutrient transport into a single multifunctional mechanism.

The water vascular system is powered by seawater, which enters through a porous structure called the **madreporite**. From there, water flows into a central **ring canal** and branches into **radial canals** that extend along the arms. Connected to the radial canals are **tube feet**, which are elongated structures that function through hydraulic pressure.

By contracting and relaxing the **ampullae**, bulb-like structures at the base of each tube foot, echinoderms can control water flow and generate movement. This hydraulic system allows them to attach to surfaces, manipulate prey, or move across the seafloor with remarkable precision.

In addition to locomotion, the water vascular system supports basic circulatory functions by distributing nutrients and removing waste. However, because it relies entirely on external seawater, the system is highly sensitive to changes in salinity, pH, and other environmental factors. This environmental dependency highlights the adaptability of echinoderms to stable marine habitats while underscoring the limitations of this unique circulatory system.

**Phyla with Water Vascular System**: Echinodermata.

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