# Section 3: Circulatory System Variations Among Major Invertebrate Groups

The circulatory systems of invertebrates are remarkably diverse, reflecting adaptations to specific environmental conditions and lifestyles. In this section, we examine the unique circulatory features within select groups, emphasizing the variation and evolutionary modifications that support their survival.

**Mollusca: Open vs. Closed Circulatory Systems**

Mollusks exhibit significant variation in their circulatory systems, ranging from fully open systems in gastropods and bivalves to the highly efficient closed systems of cephalopods.

* **Gastropods (Snails, Slugs)**: Gastropods possess open circulatory systems where hemolymph flows freely in a haemocoel, bathing the organs. This system is well-suited for their relatively slow movement and low metabolic demands. The heart pumps hemolymph into short vessels, but precise delivery is unnecessary given their sluggish lifestyles.
* **Bivalves (Clams, Oysters)**: Bivalves also rely on an open system, which is sufficient for their sedentary or burrowing lifestyles. The hemolymph delivers nutrients and removes waste but is not heavily involved in gas exchange, which occurs primarily across the gills.
* **Cephalopods (Squids, Octopuses)**: Cephalopods have evolved closed circulatory systems to support their active, predatory lifestyles. Their three hearts—two branchial and one systemic—work together to ensure rapid and efficient oxygen delivery. However, even among cephalopods, variations exist:
  + The gills in some cephalopods function as partially open systems, allowing hemolymph to flow freely in localized regions. This compromise reduces vascular resistance without significantly affecting oxygenation efficiency.
  + Highly active cephalopods like squids have a more thoroughly closed system, ensuring rapid oxygenation to support burst swimming and prolonged activity.

This range of circulatory adaptations highlights the interplay between metabolic demands and the efficiency of transport mechanisms in mollusks.

### Species Profile: Vampire Squid (Vampyroteuthis infernalis)

**Circulatory System**: Closed system with partial vascularization in the gills.  
The vampire squid, a deep-sea cephalopod, has a closed circulatory system with three hearts. The branchial hearts pump blood to the gills for oxygen exchange, while the systemic heart circulates oxygenated blood throughout the body. However, unlike most cephalopods, the vampire squid's gills exhibit **partial vascularization**, where some hemolymph flows freely. This feature allows the species to reduce vascular resistance and conserve energy in the low-oxygen, high-pressure environments of the deep sea.

**Annelida: Adaptations in Closed Circulatory Systems**

Annelids, such as earthworms and polychaetes, are among the first invertebrates to evolve a fully **closed circulatory system**. This system is characterized by blood confined within vessels, which enables efficient nutrient and gas delivery throughout their segmented bodies.

One of the most distinctive features of annelid circulatory systems is their **aortic arches**, muscular structures that serve as auxiliary pumps. In earthworms, these arches surround the esophagus and function as "hearts," maintaining pressure and directing blood flow. The dorsal blood vessel serves as the primary pump, moving blood anteriorly, while the ventral vessel transports blood posteriorly. This segmentation allows annelids to regulate flow locally, supporting their burrowing and locomotory behaviors.

Annelids also exhibit cutaneous respiration, where gas exchange occurs across their moist skin. This adaptation reduces the reliance on gills or specialized respiratory structures, aligning with their closed circulatory system to maintain oxygen delivery even in low-oxygen environments.

**Arthropoda: Variation Between Crustaceans and Insects**

Arthropods rely predominantly on **open circulatory systems**, but significant variation exists between crustaceans and insects in how these systems function and integrate with other physiological processes.

* **Crustaceans**: While most crustaceans have open circulatory systems, many exhibit **partial vascularization**, particularly in their gills. The heart pumps hemolymph into arteries that lead to the gills, where gas exchange occurs before hemolymph flows freely into the haemocoel. This partial vascularization supports higher activity levels compared to insects, allowing crustaceans to thrive in aquatic environments with fluctuating oxygen availability. Larger crustaceans, like crabs and lobsters, exhibit more advanced circulatory features, reflecting their higher metabolic demands.
* **Insects**: In contrast, insects rely on their **tracheal system** for oxygen delivery, which bypasses the circulatory system entirely. The dorsal heart pumps hemolymph primarily for nutrient and hormone distribution, as well as waste removal. This uncoupling of gas exchange from circulation allows insects to maintain an efficient and energy-saving system, even for species with high metabolic rates, such as bees or dragonflies.

These differences underline the diversity within arthropods, where modifications to the open circulatory system align with their specific ecological niches and respiratory strategies.

**Nemertea: A Unique Closed System Without a Heart**

Nemerteans (ribbon worms) are a unique group with a **closed circulatory system**, but unlike most animals with closed systems, they lack a heart. Instead, blood is moved through their vessels by the contractions of body wall muscles and the peristaltic action of the vessels themselves.

This system is relatively slow compared to other closed systems but remains sufficient for the nemerteans' lifestyles. Nemerteans rely on **cutaneous respiration**, where oxygen diffuses directly across their skin into the blood. The simplicity of this system reflects their relatively low metabolic demands and the lack of coupling between their circulatory and respiratory systems.

The nemertean circulatory system exemplifies how closed systems can evolve to meet the minimal requirements of specific ecological contexts, trading speed and efficiency for simplicity and energy conservation.

### Species Profile: Bootlace Worm (Lineus longissimus)

The bootlace worm, Lineus longissimus, is a nemertean known for its extraordinary length, with some individuals reaching over 180 feet (55 meters), making it one of the longest animals in the world. Despite this impressive size, it relies on a simple **closed circulatory system** without a true heart. Instead, blood is moved through vessels by the contraction of body wall muscles and peristaltic motion of the vessels themselves. This slow circulation is sufficient because the worm primarily relies on **cutaneous respiration**, where oxygen diffuses directly through its skin. The closed system allows the bootlace worm to distribute nutrients and waste efficiently over its massive body length while minimizing energy expenditure—a critical adaptation for its slow-moving, predatory lifestyle in shallow marine environments.

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