# Section 2: Body Plan and Anatomy

The body plan of chordates is defined by five hallmark features: the **notochord**, **endostyle**, **dorsal hollow nerve cord**, **pharyngeal slits**, and **post-anal tail**. These features provide the structural, functional, and developmental foundation for all chordates and are critical to understanding their evolutionary success. This section explores these features in depth, emphasizing the **notochord** and **endostyle**, while highlighting their roles in **Urochordata** and **Cephalochordata**.

**Key Shared Anatomical Features**

**The Notochord**

**Structure**:  
 The notochord is a flexible, rod-like structure that provides skeletal support. It consists of stiff, disk-like cells arranged longitudinally and encased in a fibrous sheath. This arrangement can be compared to a **roll of coins wrapped in paper**, where the "coins" represent the rigid cells and the paper represents the tensile sheath. The spacing between these “coins” determines the balance between flexibility and support: tightly packed disks provide greater rigidity, while loosely arranged disks allow for more movement but less stability.

**Function**:  
 The notochord serves as a scaffold for the body, enabling chordates to move with coordinated, undulating motions. Its ability to bend without compressing makes it particularly effective for locomotion in aquatic environments. By acting as a central axis, the notochord also helps maintain the body’s shape and resists external pressures during movement.

**Role in Chordate Groups**:  
 In **urochordates**, the notochord is present only in the larval tail, supporting swimming during this dispersal phase. In **cephalochordates**, the notochord extends the entire length of the body and persists throughout life, serving as the primary skeletal structure for burrowing and swimming. In **vertebrates**, the notochord is replaced by the vertebral column during development, but it remains essential in early embryogenesis as a scaffold for vertebra formation and persists as part of the intervertebral discs.

**The Endostyle**

**Structure**:  
 The endostyle is a mucus-secreting groove located along the ventral floor of the pharynx. It is lined with specialized cells, including **mucus-secreting cells**, **iodine-binding cells**, and **ciliated cells**. These cells work together to trap and transport food particles while also absorbing and storing iodine. The cilia along the endostyle beat in a coordinated manner to move mucus and captured particles toward the digestive tract.

**Function**:  
 The primary role of the endostyle is **filter feeding**. As water flows into the pharynx, food particles become ensnared in the mucus produced by the endostyle. This mucus, now laden with food, is transported by ciliary action to the esophagus for digestion. Additionally, the endostyle is involved in **iodine metabolism**, binding iodine to proteins in a process that is homologous to the function of the vertebrate thyroid gland.

**Role in Chordate Groups**:  
 In **urochordates**, the endostyle is highly specialized for filter feeding, working in tandem with the pharyngeal basket to trap and process food as water flows through the body. In **cephalochordates**, the endostyle similarly traps food particles and moves them toward the digestive system, playing a central role in their filter-feeding mechanism. In **vertebrates**, the endostyle evolves into the **thyroid gland**, which secretes hormones that regulate metabolism and iodine processing. This evolutionary transformation underscores the shared ancestry of vertebrates and non-vertebrate chordates.

**The Dorsal Hollow Nerve Cord**

**Structure**:  
 The dorsal hollow nerve cord is a tubular structure located above the notochord. Unlike the solid and ventral nerve cords found in other phyla (e.g., arthropods and annelids), the chordate nerve cord is hollow and dorsal, allowing for the development of a more complex central nervous system.

**Function**:  
 The nerve cord serves as the primary conduit for neural signals, coordinating movement and processing sensory information. Its hollow structure provides the foundation for the development of a centralized brain and spinal cord in vertebrates.

**Role in Chordate Groups**:  
 In **urochordates**, the nerve cord functions in the larval stage to coordinate swimming. As adults, their nervous system simplifies into a basic ganglion for rudimentary sensory and motor functions. In **cephalochordates**, the nerve cord persists throughout life, playing a key role in movement and sensory integration. In **vertebrates**, the dorsal hollow nerve cord develops into the **brain** and **spinal cord**, centralizing control of complex behaviors and bodily functions.

**Pharyngeal Slits**

**Structure and Function**:  
 Pharyngeal slits are openings in the pharynx that allow water to pass through while trapping food particles or facilitating gas exchange. They are lined with cilia or mucus to aid in filtering or respiration.

**Role in Chordate Groups**:  
 In **urochordates** and **cephalochordates**, the pharyngeal slits function as part of the filter-feeding apparatus. In **vertebrates**, the slits are modified into structures such as gills in fish or components of the jaw and ear in terrestrial species, demonstrating their versatility across evolutionary time.

**Post-Anal Tail**

**Structure and Function**:  
 The post-anal tail extends beyond the anus and is supported by the notochord or vertebral column. It provides propulsion in aquatic environments, enabling efficient swimming through coordinated movements.

**Role in Chordate Groups**:  
 The tail is particularly prominent in aquatic chordates such as **urochordate larvae** and **cephalochordates**, where it aids in locomotion. In many vertebrates, it persists as a key locomotory or balancing structure, though it may be reduced or absent in some species.

**Group-Specific Anatomical Features of Non-Vertebrate Chordates**

The two non-vertebrate subphyla of chordates, **Urochordata** (tunicates) and **Cephalochordata** (lancelets), showcase distinct adaptations that set them apart from one another and from vertebrates. This section delves into their unique anatomical features, emphasizing their specialized feeding structures and ecological strategies.

**A. Urochordata (Tunicates)**

**The Tunic**  
 The defining feature of tunicates is the **tunic**, an outer covering composed of **tunicin**, a cellulose-like carbohydrate. This structure is unique among animals and serves several roles:

* **Protection**: The tunic shields tunicates from predators, environmental stress, and physical damage.
* **Support**: It provides structural integrity to the body, particularly in sessile species.
* **Symbiotic Relationships**: In some tunicates, the tunic harbors symbiotic microorganisms, which may contribute to defense by producing chemical deterrents.

The tunic varies in texture, thickness, and transparency across tunicate species. For example, sessile sea squirts often have thick, leathery tunics, while pelagic species like salps possess thinner, more gelatinous coverings to enhance buoyancy.

### Species Profile: Molgula manhattensis (Sea Grape)

This small, round tunicate, also called the "sea grape," is an invasive species found in coastal regions worldwide. Its thick, gelatinous tunic allows it to resist desiccation and fouling, enabling it to spread rapidly via ship hulls and aquaculture equipment. While harmless-looking, Molgula manhattensis outcompetes native species, altering ecosystems and threatening biodiversity. Its impressive survival strategy highlights the ecological challenges posed by invasive non-vertebrates.

**Siphons and the Pharyngeal Basket**  
 Tunicates use a pair of siphons for feeding and respiration:

* **Incurrent Siphon (Oral Siphon)**: This siphon draws water and food particles into the body cavity. The water flows into the **pharyngeal basket**, a sieve-like structure lined with mucus secreted by the endostyle.
* **Excurrent Siphon (Atrial Siphon)**: Filtered water and waste are expelled through this siphon, creating a unidirectional flow that maximizes feeding efficiency.

The pharyngeal basket is perforated with numerous **pharyngeal slits**, which allow water to pass through while trapping suspended food particles. These particles are carried by ciliary action to the digestive system. This system enables tunicates to filter vast amounts of water, feeding on plankton and organic debris.

### Species Profile: Ascidia sydneiensis

This hardy sea squirt thrives in polluted harbors and urban coastal areas, tolerating low oxygen levels and high contaminant loads. Its ability to survive in harsh environments makes it a focus of ecological studies on pollution tolerance and biofouling. Despite its unassuming appearance, Ascidia sydneiensis plays an important role in filtering particulates and improving water quality in degraded habitats.

**Variations Among Tunicates**  
 Tunicates are divided into three major classes, each with unique structural and ecological traits:

* **Ascidiacea (Sea Squirts)**:
  + **Lifestyle**: Sessile as adults, attaching to rocks, shells, or other substrates.
  + **Body Structure**: Barrel-shaped, with siphons facing outward to optimize water flow. Sea squirts typically have thick, leathery tunics for protection.
  + **Feeding**: Utilize their large pharyngeal baskets for efficient filter feeding.

### Species Profile: Ciona intestinalis (Sea Squirt)

Known as the "sea squirt," Ciona intestinalis is a tunicate model organism in developmental biology. With its translucent body, it provides scientists with a window into early chordate development. This species is sessile, attaching to rocks or docks in shallow waters, where it filters plankton through its pharyngeal basket. Its genome has been fully sequenced, revealing insights into the evolution of vertebrate traits and the conservation of genetic pathways across chordates.

### Species Profile: Salpa maxima (Giant Salp)

The giant salp, from the **Thaliacea** class, is a free-floating tunicate renowned for its size and bioluminescence. Often forming chains over 10 meters long, Salpa maxima drifts through open oceans, feeding on microscopic plankton. Despite their delicate, gelatinous bodies, salps play a critical role in the marine carbon cycle, consuming phytoplankton and sinking carbon to the ocean depths as fecal pellets. Their ability to glow in the dark adds a touch of wonder to the deep seas, creating mesmerizing light shows.

* **Appendicularia (Larvaceans)**:
  + **Lifestyle**: Free-living and planktonic, retaining larval features throughout life (neoteny).
  + **Body Structure**: Small and tadpole-like, with no significant tunic. Instead, they construct mucous "houses" that act as intricate filtration systems.
  + **Feeding**: Mucous houses filter fine plankton and organic particles, which are ingested by the larvacean. These houses are regularly discarded and rebuilt.

### Species Profile: Oikopleura dioica

This larvacean, from the **Appendicularia** class, is a master architect of the ocean’s miniature worlds. Oikopleura dioica lives within a mucus “house,” which it builds and regularly discards as it filters plankton from seawater. These mucous structures are intricate, containing channels and filters to trap the smallest particles. This tiny tunicate is a critical player in marine ecosystems, recycling organic material and contributing to the biological pump that transfers carbon to the ocean floor.

**B. Cephalochordata (Lancelets)**

**The Oral Hood and Cirri**  
 The feeding apparatus of lancelets centers on the **oral hood**, a funnel-like structure at the anterior end of the body. This hood is lined with **cirri**, slender finger-like projections that filter water entering the pharynx.

* **Function of Cirri**:  
   The cirri act as a pre-filter, preventing large particles and debris from entering the pharynx. By regulating the size of ingested particles, the cirri ensure efficient filtering of fine organic material and plankton.

**Pharyngeal Slits and the Atrium**  
 After passing the cirri, water flows into the **pharyngeal basket**, which contains numerous **pharyngeal slits** supported by gill bars. These slits are surrounded by the **atrium**, an external cavity that collects filtered water. The **endostyle**, located along the floor of the pharynx, secretes mucus to trap food particles suspended in the water.

Cilia lining the pharynx transport the mucus and food toward the digestive tract. Filtered water exits the body through a single opening, the **atriopore**, completing the unidirectional flow.

**Feeding Efficiency**  
 Lancelets are capable of filtering large volumes of water to extract nutrients, making them highly efficient filter feeders. Their feeding mechanism is adapted for their benthic lifestyle, allowing them to remain partially buried in sediment while drawing water and nutrients into their bodies.

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