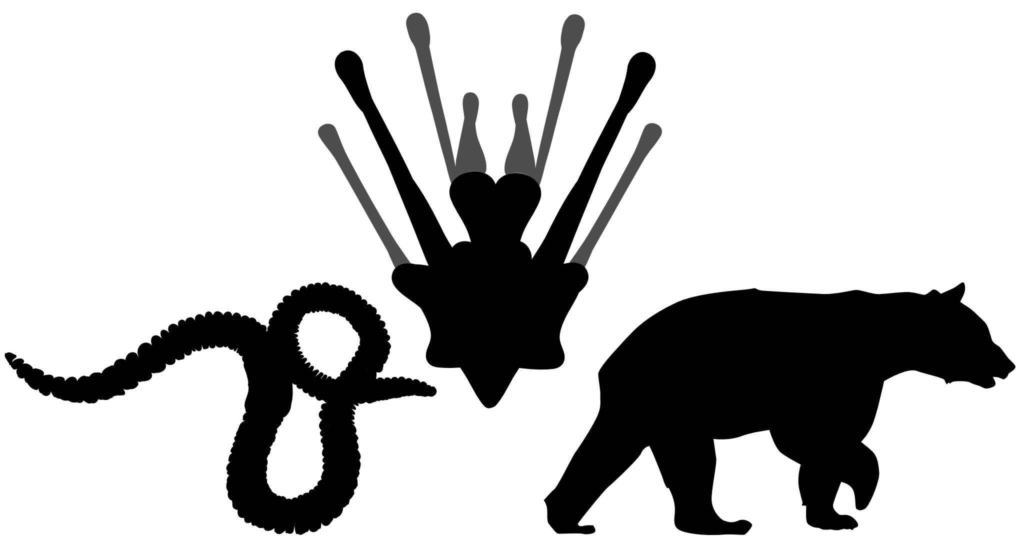
Body Systems:

Respiratory, Circulatory, Digestive and Musculoskeletal

Educators's Resource Guide



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Contents

Stop and Think

What do living things have in common? What separates living things, like plants and animals, from non-living things, like rocks and fire?

Living things share a set of features that make them different from non-living things. They are the **characteristics of life**[1].

- **Reproduction**: living things can reproduce their own kind, making **offspring** - like these grizzly bear cubs

Grizzly Bear, *Ursus arctos horribilis*
Mick Thompson - CC BY-NC 2.0

- **Energy Processing:** Anna's hummingbirds obtain fuel from the nectar of flowers, which is broken down in the body and used as energy for things like flight

Anna's Hummingbird, *Calypte anna*
Becky Matsubara - CC BY 2.0

- **Growth and Development**: information encoded in DNA controls patterns of growth and development - like when a Western toad transitions from an egg to a tadpole to an adult

Western Toad, *Anaxyrus boreas*
Jamie Clarke

- **Response to Environment**: a round-leaved sundew folds its sticky hairs to trap a damselfly in response to the stimulus of prey landing on its leaves

Round-leaved Sundew, *Drosera rotundifolia*

- **Regulation:** the regulation of blood flow in white-tailed jackrabbits' ears helps keep body temperature constant by exchanging heat with the environment

White-tailed Jackrabbit, *Lepus townsendii*

- **Order**: living things have order and organization as shown in a close look at a patch of sea sandwort

Sea Sandwort, *Honckenya peploides*

- **Evolutionary Adaptation**: the giant Pacific octopus camouflages into its surroundings - an adaptation that makes it better suited to its environment and which evolved over many generations

Pacific Octopus, *Enteroctopus dofleini*

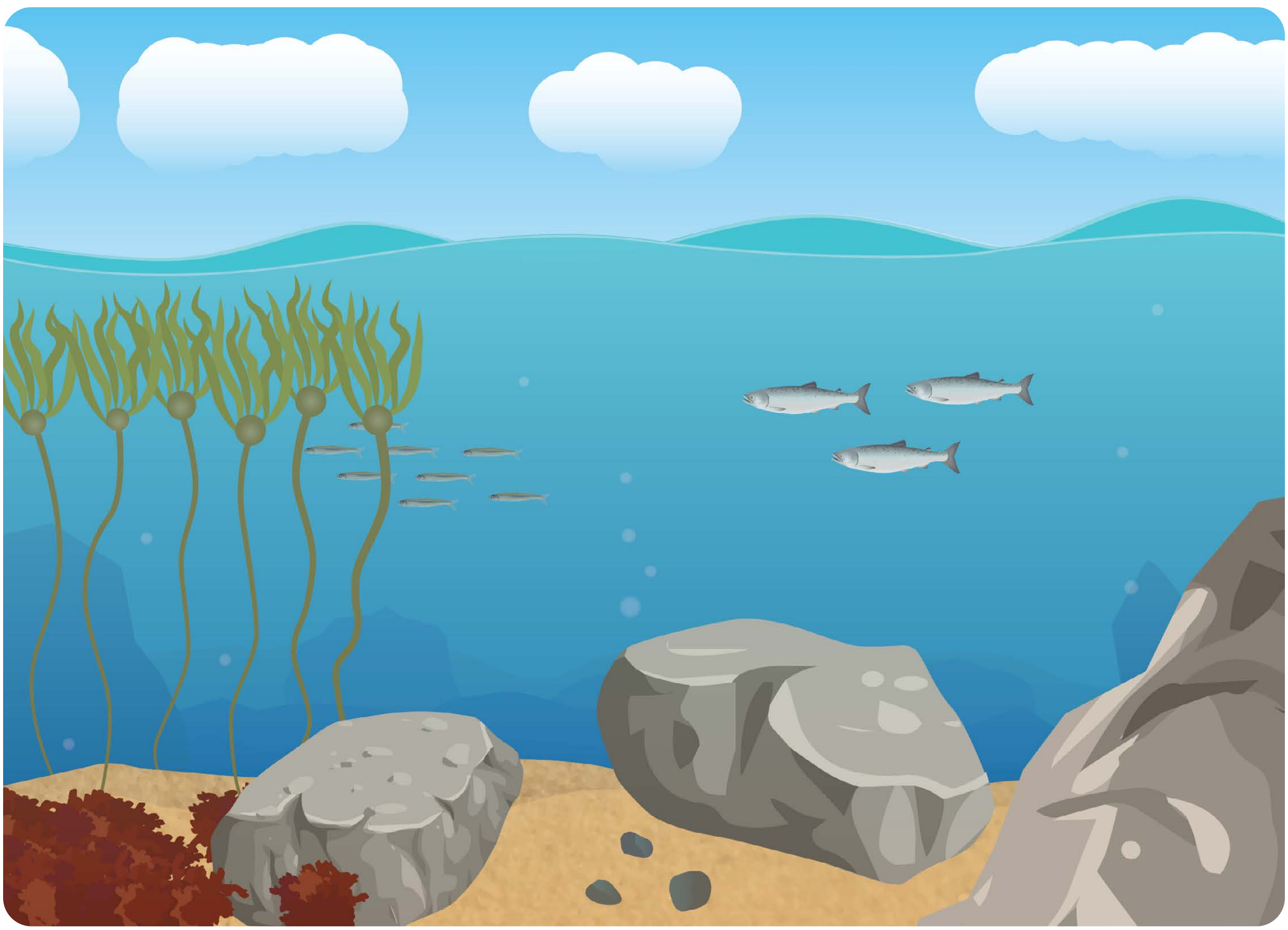
Stop and Think

A rocket ship needs fuel to move and is highly ordered and organized... Is a rocket ship a living thing?

While non-living things can have some of the characteristics of life, a living thing - an **organism** - can do *all* of these things. So while a rocket ship might use fuel to move and be highly ordered, it can't reproduce, grow or evolve; therefore, it isn't a living thing.

Class Activity

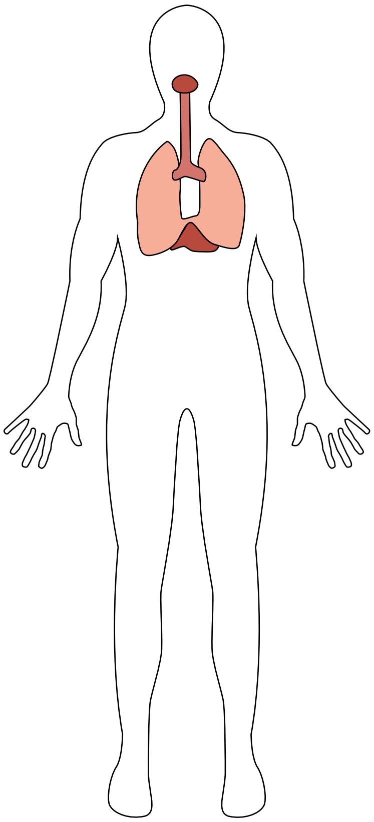
Take a look at the image below: name two living and two non-living things you can see, and explain why you classified those things as living or non-living.



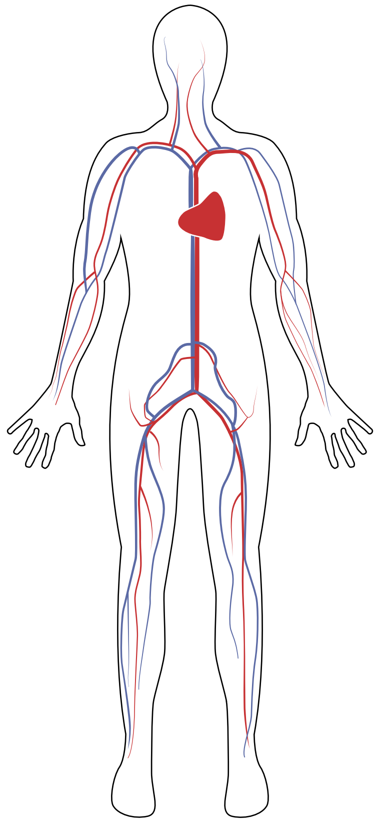
Animals are a group of organisms that carry out the essential processes of life - like obtaining and processing energy, regulating the body, and responding to the environment - using specialized **cells**, **tissues** and **organs** which are grouped into **body systems**. Cells are the smallest, most basic units of living things.[2] Tissues are groups of cells with a shared form and purpose. Organs are groups of tissues that work together to do something specific - the heart, for example, is an organ that pumps blood around the body.[3] And body systems are groups of organs that, all together, perform a function, like digestion or reproduction.[3]

First, we'll name the body systems and describe their functions in people. Then, we'll take a closer look at the body systems of organisms across the animal kingdom.

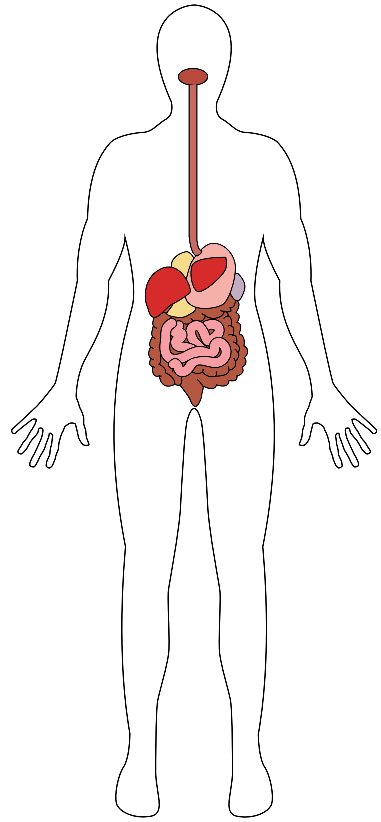
Body systems and their functions in humans



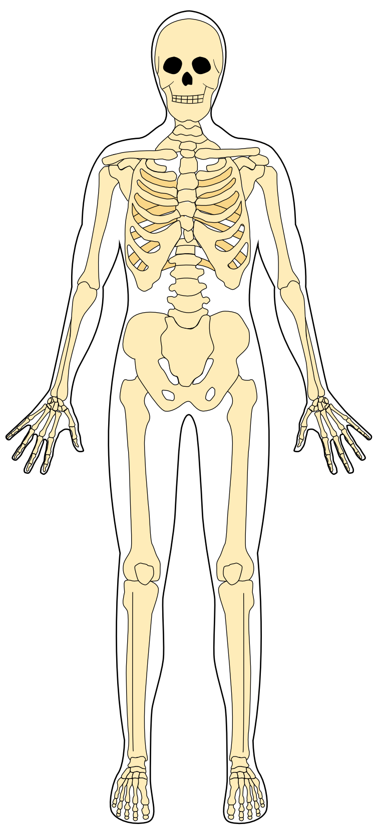
Respiratory



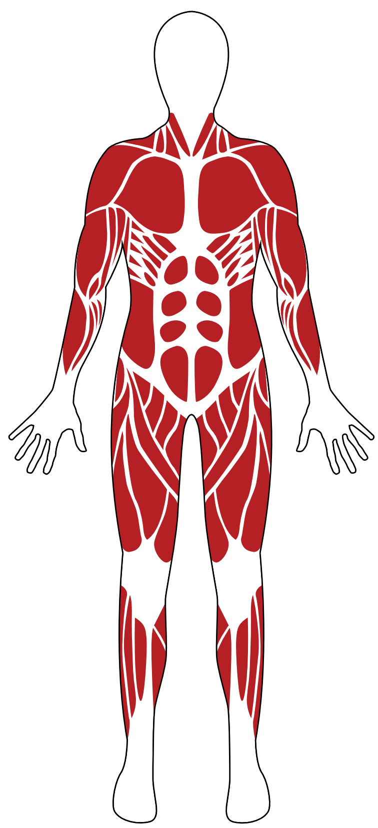
Circulatory



Digestive



Skeletal



Muscular

Body systems and their functions in humans[3,4]

- **Respiratory System**: oxygen and carbon dioxide (gas) exchange
- **Circulatory System**: transports gases, nutrients, wastes, hormones and other substance throughout the body
- **Digestive System**: breaks down food and absorbs nutrients into the body
- **Musculoskeletal System:** supports, protects and moves the body
    - **Skeleton:** system of support and movement, protects the internal organs, stores minerals, blood formation
    - **Muscles:** movement and heat production
- **Excretory System:** eliminates wastes (urine), regulates blood pH (how acidic/basic) and volume
- **Reproductive System:** produces sex cells (sperm or eggs), either transfers and deposits sperm or provides an environment and resources for fertilized egg to grow and develop
- **Nervous System:** responds to stimulus and sensations, coordinates the activities of the other body systems
- **Hormonal System:** regulates body functions using chemicals called hormones

------- Stop and Think -------

What are examples of organs that belong to these body systems?

Body systems in different animal groups

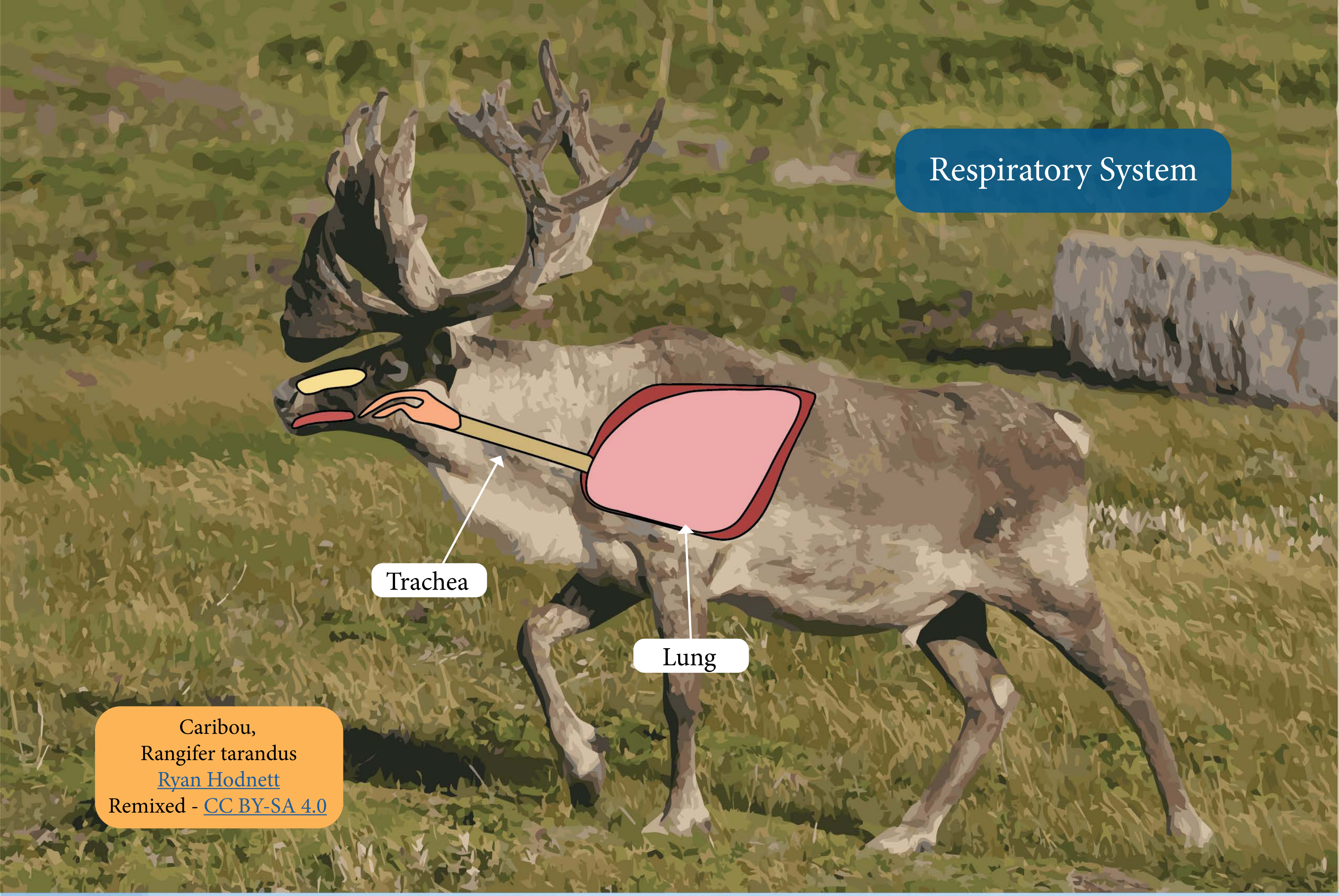
The body systems of some animals are very similar in structure and organization to our own - but some animals look and live very differently than we do. Starting with animals that are most closely related to us and moving towards increasingly distantly-related groups, let's compare body systems throughout the animal kingdom.

------- Stop and Think -------

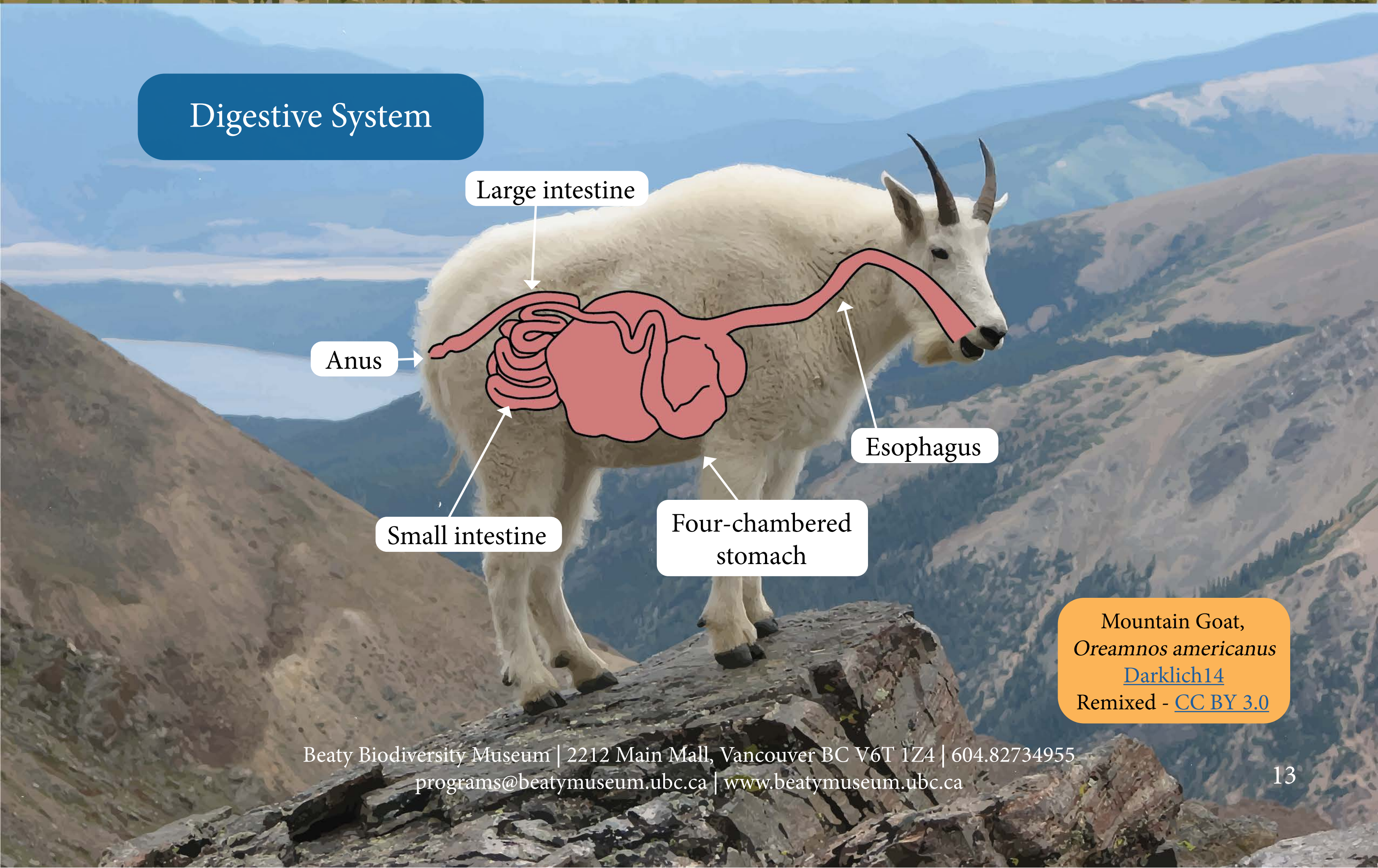
Fill in the table below as you go through the next pages: which cells/tissues/organs are a part of the body systems of each of the animal groups? Do you notice any trends or patterns?

	Respiratory	Circulatory	Digestive	Musculo- Skeletal
Mammals				
Birds				
Fish				
Echinoderms				
Insects				
Trematodes				
Sponges				

Mammals



Caribou,
Rangifer tarandus
Ryan Hodnett
Remixed - CC BY-SA 4.0



Mountain Goat,
Oreamnos americanus
Darklich14
Remixed - CC BY 3.0

Mammals[5,6,7]

Mammals are warm-blooded animals with four limbs and hair that produce milk to feed their young. Many familiar creatures belong to this group: kangaroos, mice, bears, elephants, whales, monkeys, and platypuses are all mammals… And humans are, too! Because humans are mammals, our body systems tend to be similar to those of other animals in this group.

Respiratory: Mammals - even those that live underwater, like whales and dolphins - breathe air using **lungs**. Air is drawn down from the **nostrils** or **mouth**, into the **trachea** in the throat, and through a series of ever-smaller tubes in the lungs called the **bronchi** and **bronchioles**. The bronchioles end in tiny bag-like **alveoli**, which are surrounded by webs of blood vessels. Oxygen and carbon dioxide are exchanged between the air and the blood in the alveoli. Air is brought into the respiratory system when muscles pull and expand the stretchy lungs; increasing the volume of the lungs sucks air in. When those muscles relax, the lungs compress, forcing air back out of the body.

Circulatory: Blood is circulated around the body in closed tubes, or vessels. **Arteries** are the vessels that carry blood away from the heart; **veins** are the vessels that carry blood towards the heart. The arteries branch into a network of smaller and smaller **arterioles** which lead to networks of even smaller **capillaries**. Nutrients, gases and wastes are passed between the blood and the tissues through the capillaries' single-cell-thick walls. From the capillaries, blood travels through **veinules**, which join together to form veins. Blood is moved through the body by the pumping of the muscular **heart**.

In mammals, there are two loops of blood vessels that make up the circulatory system: the first leaves the heart, travels to the tissues of the body, and returns to the heart; the second travels from the heart, to the lungs, and back to the heart again. This two-loop system is called **double circulation** because the blood passes through the heart twice during one complete circuit through the body and the lungs.

Digestive: The digestive system takes in food, breaks it down and absorbs the molecules that make it up. Food is broken down in two ways: by the movement of body parts (**mechanical digestion**) and by digestive chemicals (**chemical digestion**). Mechanical digestion makes chunks of food small enough for digestive chemicals to break them down into their components.

The first part of the mammalian digestive system is the **mouth**. There, food is broken up both mechanically and chemically. The **teeth** that line the mouth chew and rip food into smaller pieces; digestive chemicals in saliva, produced in the **salivary glands**, further break down what's been taken in. The food/saliva mixture is then swallowed with the help of the **tongue** and passes into a muscular tube called the esophagus. The **esophagus** pushes the food/saliva towards the **stomach**.

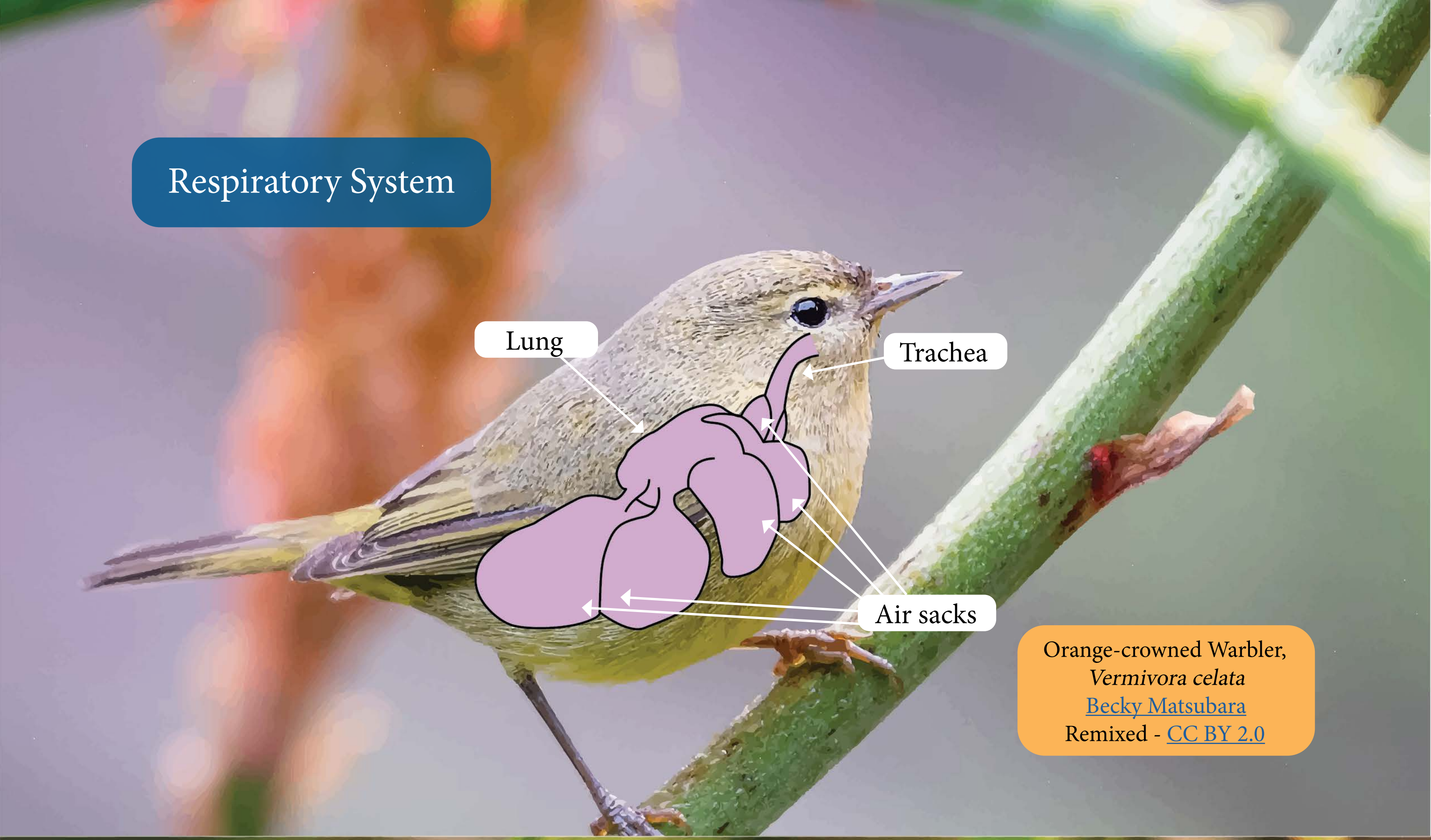
Like the mouth, the stomach mechanically digests food - by churning - and chemically digests food - by adding more digestive chemicals to the food/saliva soup. The stomach also stores food after big meals. Some herbivorous mammals have four-chambered stomachs to help them break down hard-to-digest plant materials! From the stomach, food travels into the intestines.

The intestines are the main site of chemical digestion. The **small intestine** receives substances from the **liver** and the **pancreas** that break down fats and other food molecules, and houses microorganisms like bacteria and protozoans that break down hard-to-digest plant material. Some herbivorous mammals also have a **caecum** - a bag-like offshoot of the intestine - filled with microorganisms that digest plant foods. The **large intestine**'s primary function is to reabsorb water. Undigested material (poop) passes through the large intestine and out the **anus**.

Musculoskeletal: Mammals are **vertebrates** - that is, they are animals with a spine. The **spine** extends from the neck, down the back, and all the way into the tail (if present). It provides support for the body and protects the spinal cord, the "information highway" of the nervous system. Mammals have special **vertebrae** - bones that make up the spine - in their necks that attach to the base of the **skull** and let them move their heads up-and-down (nodding) and side-to-side (shaking "no"). A set of **ribs** forms a protective cage around the delicate internal organs. Mammals also have **bones** in their limbs (fins, arms, and legs) that support them and attach to the **muscles** that move them.

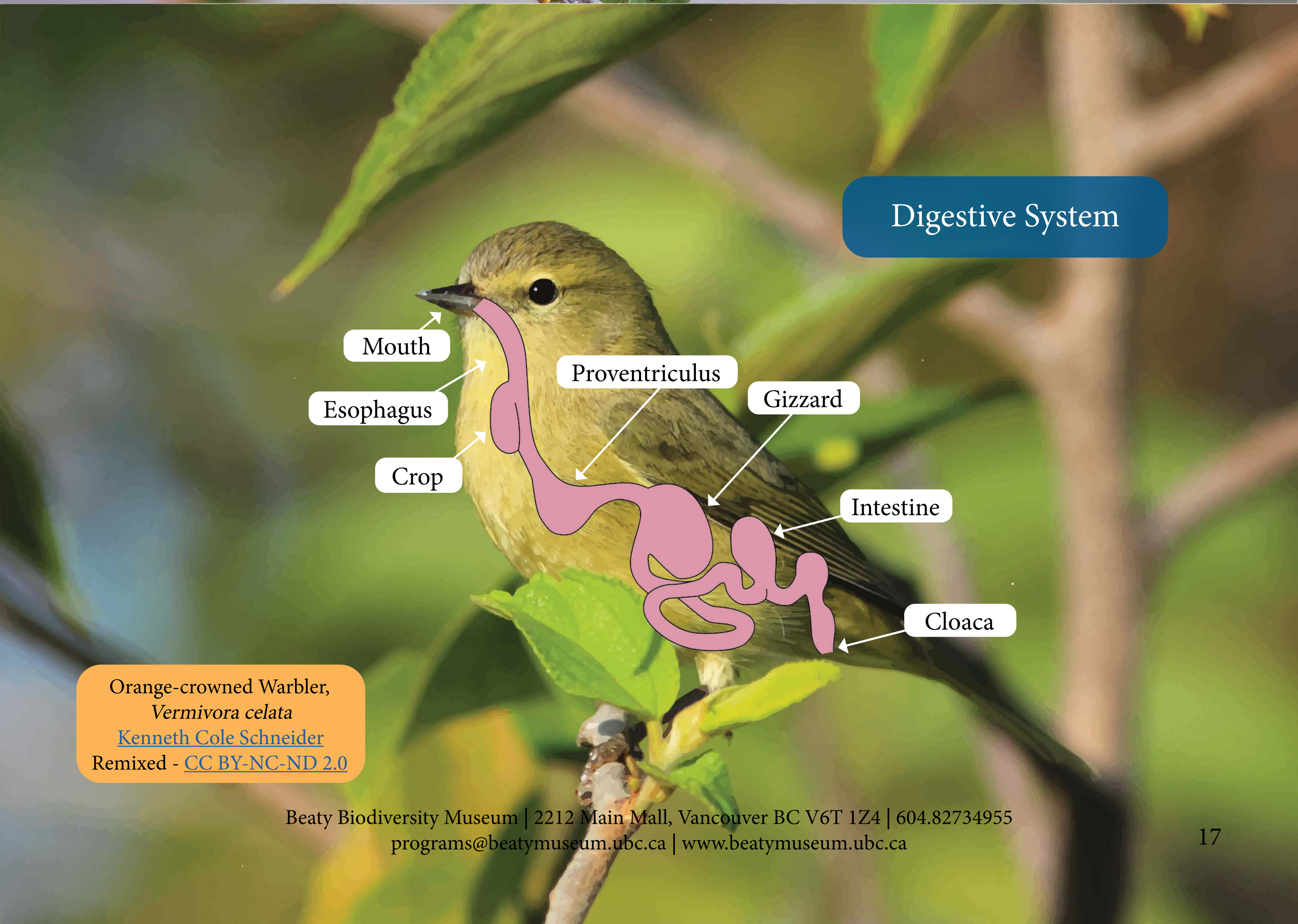
Birds

Respiratory System



Orange-crowned Warbler,
Vermivora celata
Becky Matsubara
Remixed - CC BY 2.0

Digestive System



Orange-crowned Warbler,
Vermivora celata
Kenneth Cole Schneider
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Birds[5,8,9,10]

Did you know that birds are actually small dinosaurs? This group of animals is winged, feathered and specialized for life in the air (and the water, and on land). Flight is a very energetically demanding way of moving about - so birds' bodies are specially adapted to deal with these demands.

Respiratory: Since flight is so resource-demanding, the respiratory systems of birds have evolved to be very efficient. Air enters the body through the **mouth** or **nostrils** and passes into the **trachea**. From there, it flows into a set of stretchy **air sacs** that are connected to the **lungs**. The air sacs hold air before it passes over the **parabronchi** of the lungs - the site where oxygen and carbon dioxide are exchanged between the air and the blood. Air then moves into another set of air sacs and out the body. Having airs sacs allows birds to hold air in their respiratory system and exchange gases constantly, during both inhalation and exhalation.

Circulatory: Like mammals, birds have a two-loop circulatory system. One loop carries blood to the body, and the other carries blood to the lungs. A two-loop system is called **double circulation**. Blood is pumped to the body and lungs by a muscular **heart** and travels through progressively smaller vessels (**arteries, arterioles; veins, veinules**). In the smallest vessels - the **capillaries** - substances are exchanged between the blood and the tissues of the body, or between the blood and the air in the lungs.

Digestive: The digestive systems of birds are similar to those of mammals. Food is taken into the **mouth**, travels down the **esophagus** and into the **stomach** - where it is broken up by muscular churning and digestive chemicals - before continuing on to the intestines - where it is further broken down by chemicals, and food molecules are absorbed. In addition to these structures, some birds have a bag-like bulge off of the side of the esophagus, called a **crop**, that stores food to be digested later or spat back up to feed chicks.

Birds also have a two-chambered stomach made up of the **proventriculus** and the **gizzard**. The proventriculus chemically digests food, breaking it down with acid and enzymes - much like our stomachs do. The gizzard mechanically digests food by grinding it into smaller pieces. It is an important structure because birds don't have teeth! In species that eat hard foods like seeds, the gizzard is thick-walled and muscular. Birds with hard-food diets tend to swallow sand, rocks and shells that collect in the gizzard and help grind up the food that's eaten.

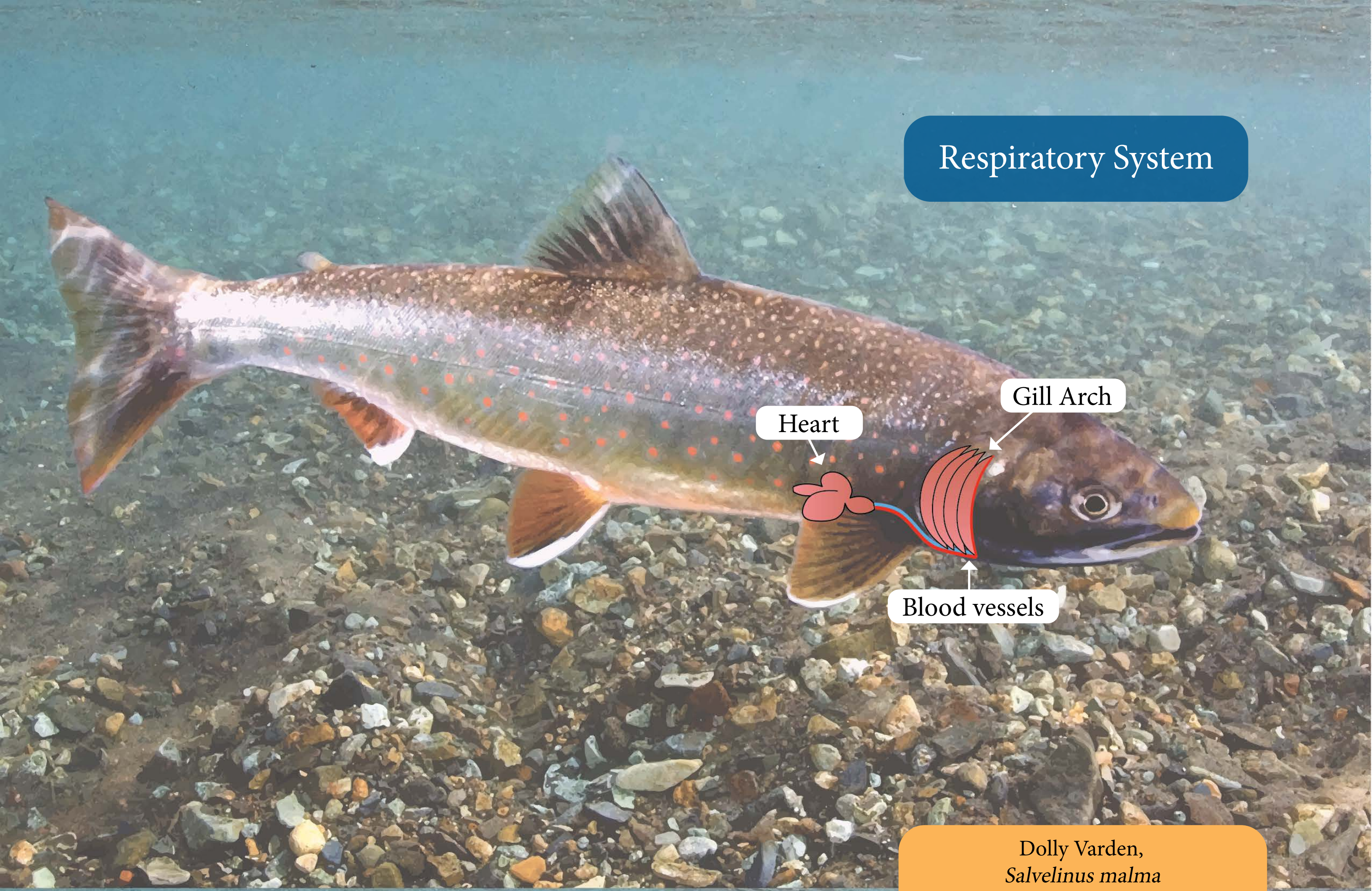
Many birds also have a pair of **colic caeca** - offshoots of the intestine, where the small and large intestine meet - which contain microorganisms that break down plant material. Undigested material (poop) leaves the body through the **cloaca**, the opening that releases products of the digestive, excretory and reproductive systems.

Musculoskeletal: Birds have skeletal adaptations that keep them light and sturdy - two important considerations for flight. One such adaptation is hollow bones. Hollow **bones** reduce body weight so birds don't have to expend as much energy heaving themselves through the air. Birds that spend a lot of their time flying tend to have more bones that are hollow. In certain places, the bones of the skeleton have also fused. Bones in the hands have been combined to strengthen and manoeuvre the wing; many vertebrae in the back have fused and combined with bones in the pelvis for stability and support during takeoff and landing; vertebrae in the tail have come together to support and control tail feathers for braking and steering.

The **vertebrae** of the neck are highly mobile, and include two special vertebrae at the base of the **skull** that allow the head to move both side-to-side and up-and-down. Where the **ribs** meet, a bony protrusion called the **keel** provides a site for flight muscles to attach. Importantly, the **muscles** that power flight are very large and strong.

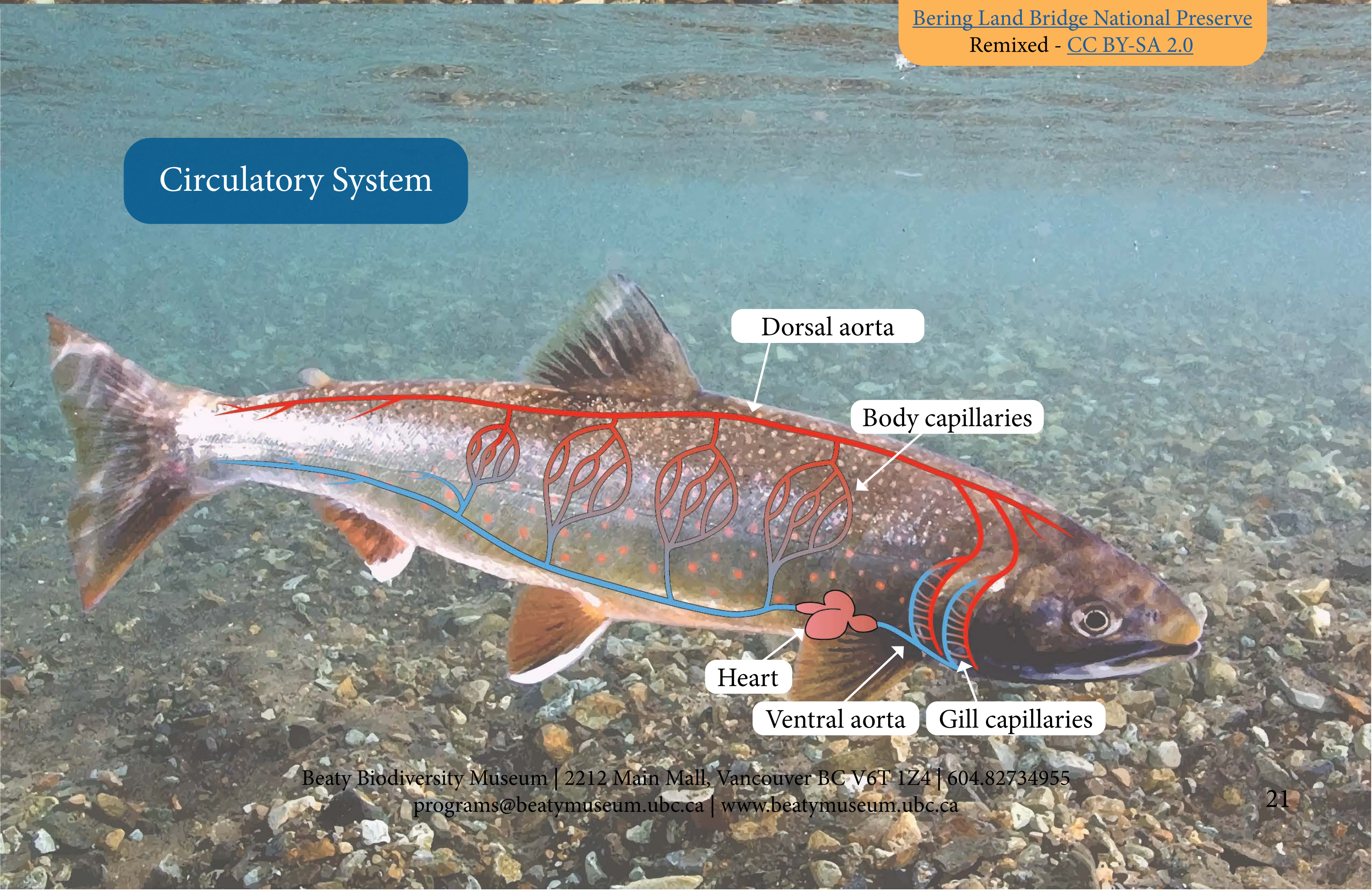
Fish

Respiratory System



Dolly Varden,
Salvelinus malma
[Bering Land Bridge National Preserve]

Circulatory System



Fish[5,12]

Fish are scaly, finned, gill-breathing animals adapted to life underwater (with a few exceptions). They are the group of true vertebrates most closely related to **invertebrates** - animals without a spine. They are also the group that gave rise to the four-legged vertebrates (**tetrapods**) like amphibians, birds and mammals.

Respiratory: Fish exchange oxygen and carbon dioxide with water using **gills**. In sharks and their relatives, the gills are divided by walls and held in small **parabranchial chambers**, which open up as slits on the outside of the body. In other fish, the gills are housed all together in large **opercular chambers** on each side of the head, behind the mouth. The opercular chambers are protected from the environment by a cover called an **operculum**. All fish take water in through the **mouth** and pass it into the gill chambers, where it washes over the thin, blood-vessel-filled gill filaments. Some fish also breathe air. Air-breathing organs in fish include the **skin** of the mouth or throat, specialized parts of the digestive tract, **gas bladders** or **lungs**, and a folded bone called a **labyrinth organ**.

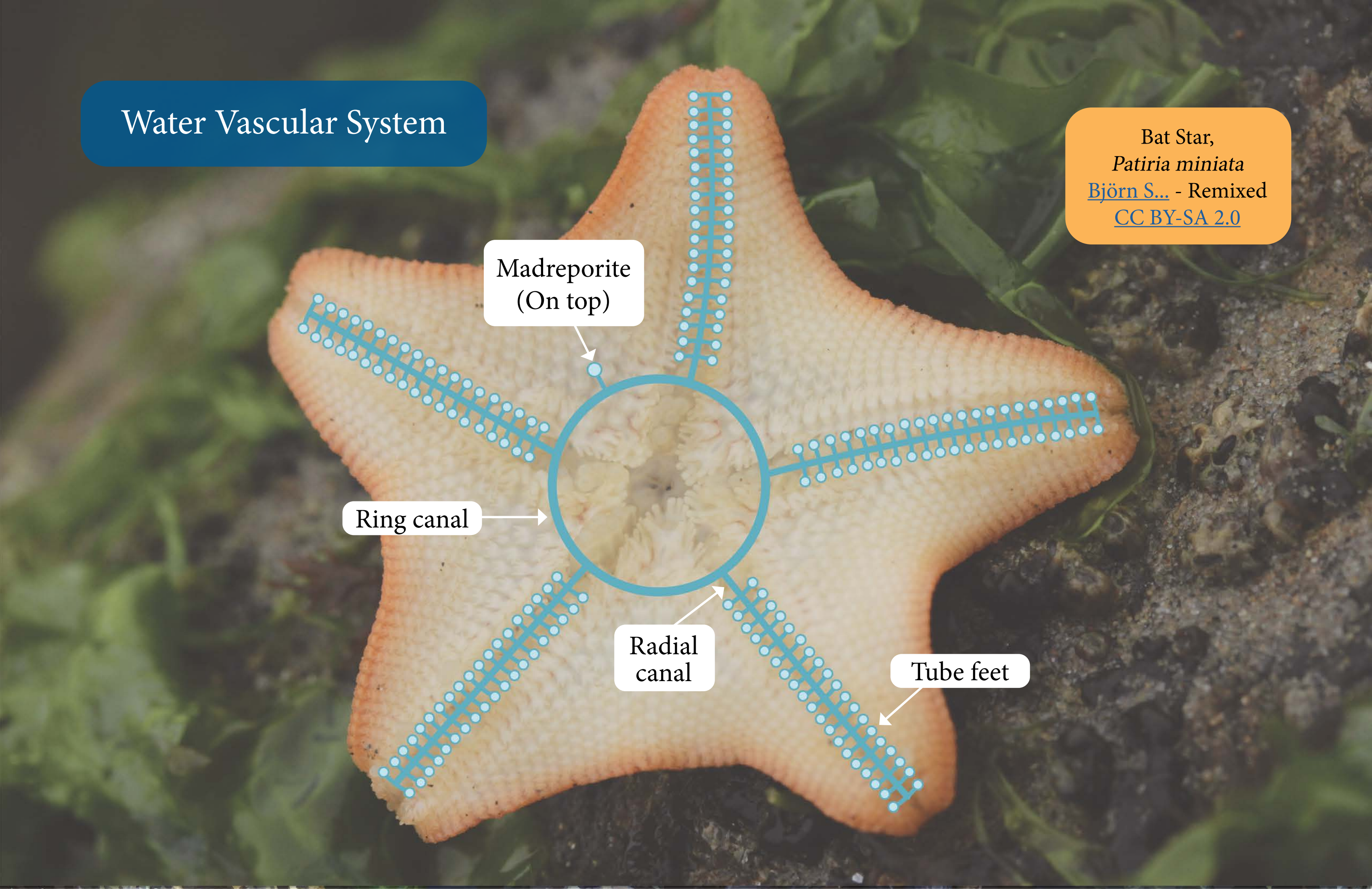
Circulatory: Unlike mammals, and birds, blood flows in a single loop through the bodies of fish (**single circulation**). From the **heart**, blood is pumped into a vessel called the **ventral aorta**. The ventral aorta branches into the smaller blood vessels - the **aortic arches** - of the gills, where gas exchange happens. Oxygen-rich blood funnels out of the aortic arches into the larger **dorsal aorta** and out to the tissues of the body, where nutrients, gases and other substances are exchanged through the thin **capillaries**. Oxygen-depleted blood returns to the heart.

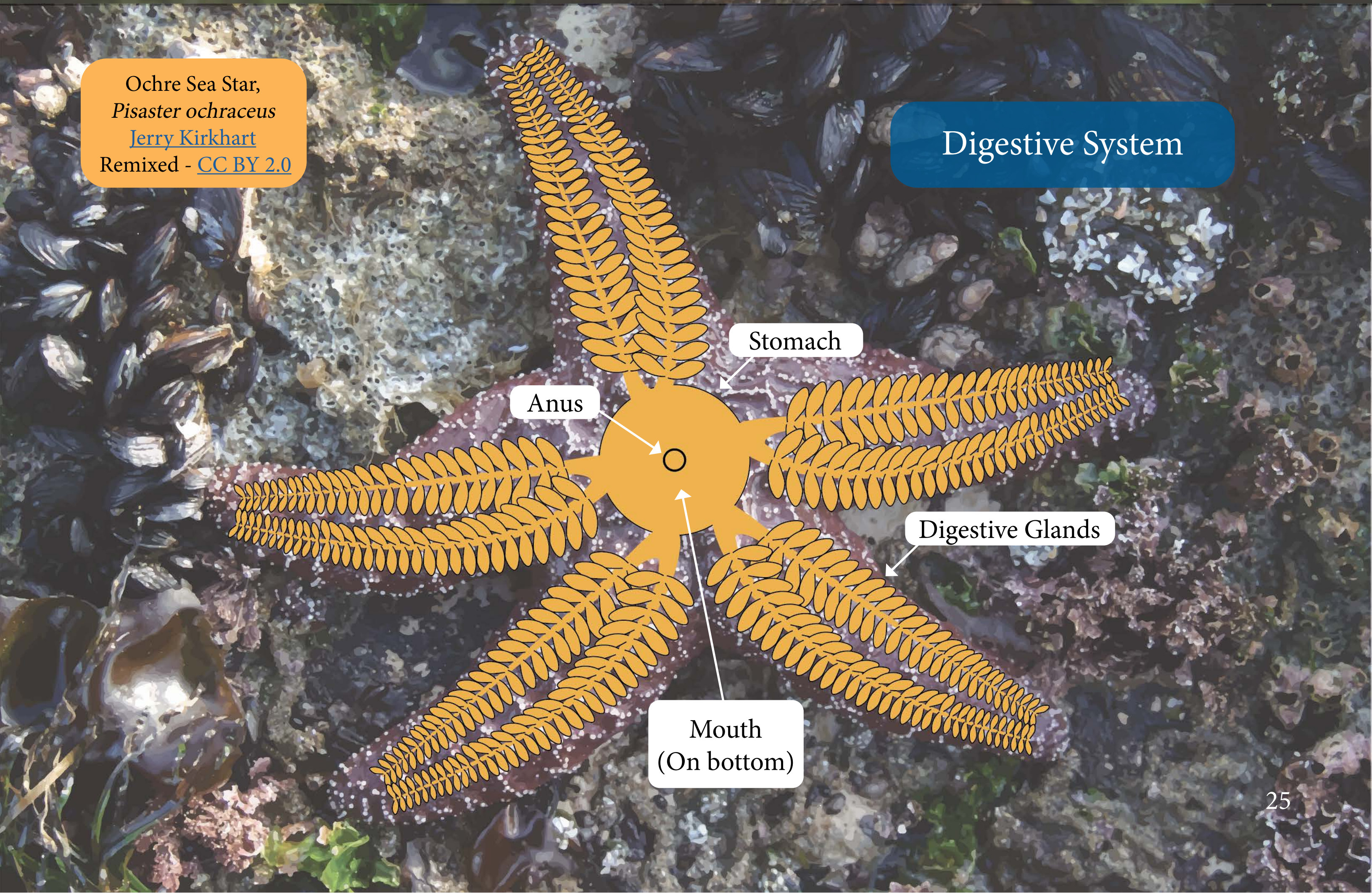
Digestive: The digestive systems of fish share many parts with the digestive systems of other vertebrates. Food is taken in through the **mouth** and passes through the throat to the **esophagus**. Most fish have **teeth** to help them grab onto, slice and grind up food. Fish that feed by filtering particles out of the water have structures called **gill rakers** that stick out in the throat to catch little organisms or pieces of food. To prevent water from being taken into the digestive system when breathing - that is, when taking in water through the mouth and pushing it over the gills in the gill chambers - the esophagus stays closed until food is swallowed. Food is broken down by the digestive chemicals and churning action of the **stomach** and is passed onto the **intestines** for further break-down and absorption of nutrients. Many fish also have small offshoots at the point where the stomach and intestines meet called **pyloric ceca**. Food is digested and absorbed there, too. The digestive system exits the body at the **cloaca**.

Musculoskeletal: Sharks, skates, rays and ratfish are fishes with skeletons made of **cartilage**. Other types of fish have skeletons made of **bone**. Fish are vertebrate animals, so they have a **spine** to support their bodies and protect the spinal cord. Attached to some of the vertebrae of the spine are **ribs** that protect important internal organs. Fish do not have the special vertebrae that allow them to move their heads up-and-down or side-to-side like tetrapods do, but they do have **skulls**.

Fish use **fins** to swim, brake, steer and stabilize themselves. There are two sets of paired fins on a fish's body: the **pectoral fins** at the front end and the **pelvic fins** at the back end. These pairs of fins evolved into the legs (and other limbs) of terrestrial animals. Pectoral and pelvic fins are supported by long, thin pieces of cartilage or bone arranged in a fan shape, called **fin rays**. Other fins on a fish's body - the **dorsal fin** running along the back, the **anal fin** on the belly, and the tail or **caudal fin** - are also supported by fin rays, if present. The group of fishes most closely related to tetrapods had fleshy fins with **muscles** and **joints** and fin rays at their tips. Fish have strong muscles that attach to their spines and squeeze to bend the body side to side, moving the tail back and forth to swim.

Echinoderms


Water Vascular System
Bat Star,
Patiria miniata
Björn S... - Remixed
CC BY-SA 2.0
Madreporite
(On top)
Ring canal
Radial
canal
Tube feet


Ochre Sea Star,
Pisaster ochraceus
Jerry Kirkhart
Remixed - CC BY 2.0
Digestive System
Stomach
Anus
Digestive Glands
Mouth
(On bottom)

Echinoderms[4,13,14,15]

While echinoderms like sea stars, sea urchins and sea cucumbers may not look much like you or me, they are actually some of our closest invertebrate relatives! All echinoderms live in the ocean - so their bodies are especially adapted to life underwater. One of the most important of these adaptations is the **water vascular system**: a series of internal tubes and tanks through which water is circulated. The water vascular system does many of the things our different body systems do using only the flow of water. It is unique to echinoderms and is particularly well-suited to a slow-moving life on the bottom of the sea.

Respiratory: Instead of using lungs or gills to breathe, echinoderms exchange oxygen and carbon dioxide with the environment through their **tube feet** - small, spindly, leg-like feelers that are a part of the water vascular system. Gases are exchanged between the water and the body through the tube feet's thin walls. Gases diffuse across other, similar body parts, as well.

Circulatory: The water vascular system transports gases, nutrients and wastes throughout the body - much like blood does in our bodies. Another system, called the **haemal system**, circulates materials around the body, too. Like the water vascular system, the haemal system is made up of a network of tubes and tanks.

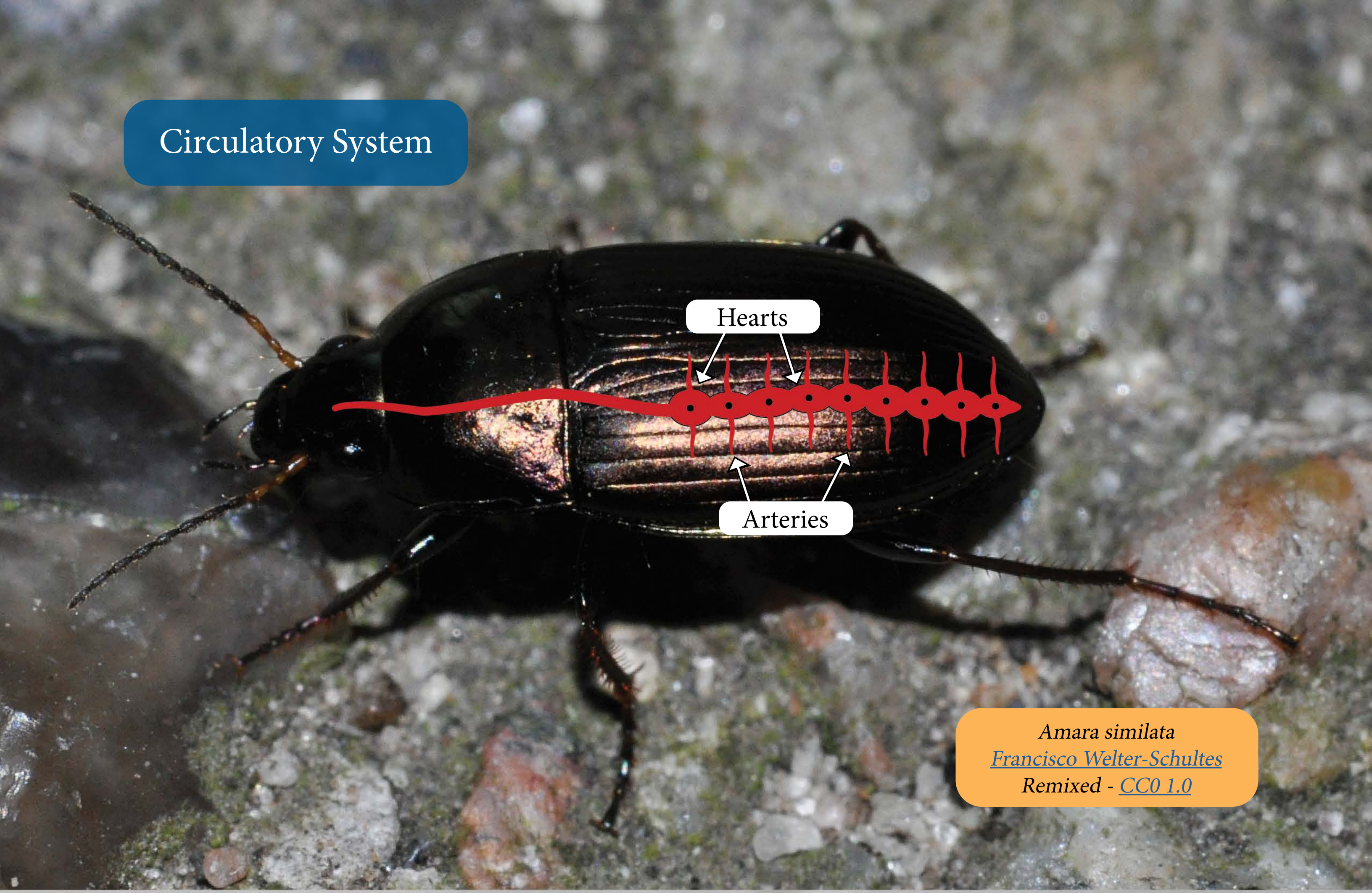
Digestive: The digestive systems of most echinoderms are **complete**, with a mouth and an anus connected by a series of digestive organs. Depending on the species, there may be **intestines** and/or none, one or several **stomachs**. Many sea stars can bring part of their stomach outside of their bodies (**eversion**) to take in food. Some sea stars that can evert their stomachs also release digestive chemicals which turn their prey into a nutritious soup before being slurped up and processed. A local species of sea star, *Pisaster ochraceus*, can insert its thin and flexible stomach into the shells of its prey - mussels, barnacles, limpets and snails - digesting and liquifying them in their own protective coverings. Some kinds of echinoderms have tube feet that catch and collect small food particles from the water.

Musculoskeletal: Echinoderms have an internal skeleton made up of **ossicles** - small bone-like plates. In some groups, the tiny ossicles are spread out throughout the body. In others, the ossicles have fused together to make big, inflexible plates or a shell-like **test** - the round, enclosing skeleton of a sea urchin. Ossicles may fuse to make defensive spines, as well.

Many echinoderms' legs and bodies are lined with tube feet that work together to crawl and flip the echinoderm right-side up. The flow of water through the water vascular system moves the tube feet. **Muscles** contract to create a suction-like seal between the feet and a surface; the tube feet also produce a sticky glue that helps them hold onto things.

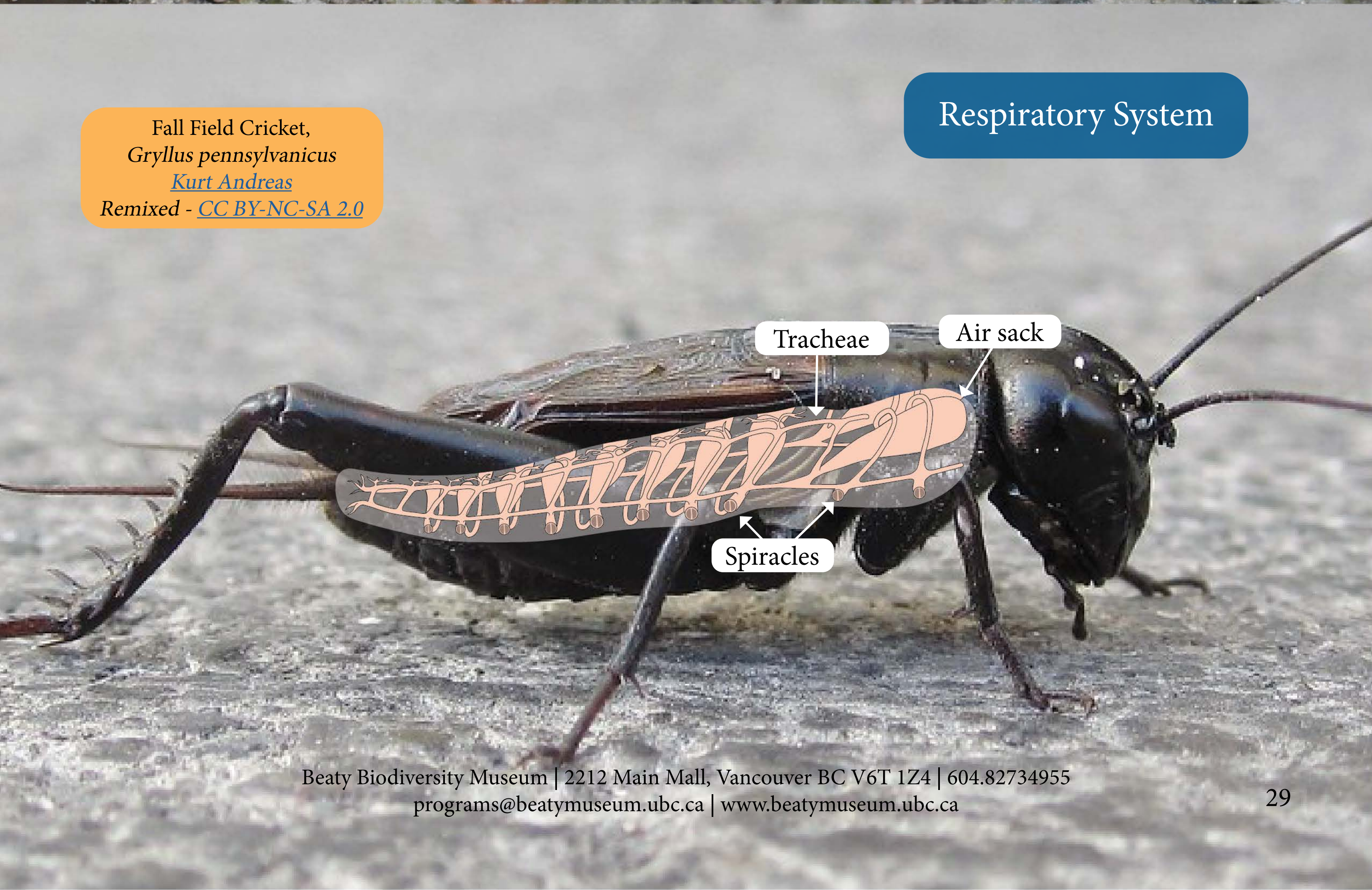
Insects

Circulatory System



Amara similata
[Francisco Welter-Schultes]
Remixed - [CC0 1.0]

Respiratory System



Fall Field Cricket,
Gryllus pennsylvanicus
[Kurt Andreas]
Remixed - [CC BY-NC-SA 2.0]

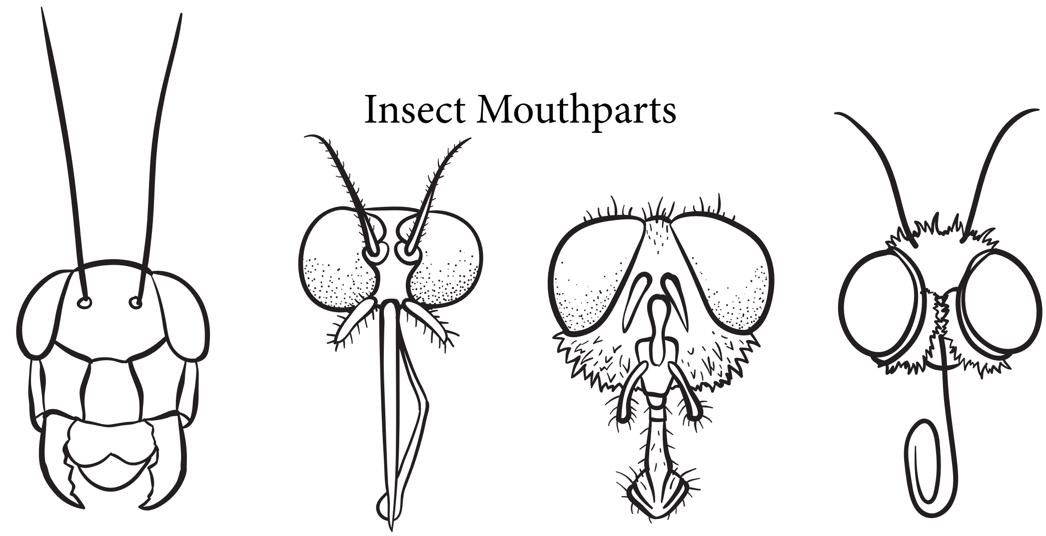
Insects[4,13,16,17,18]

Insects are amazingly diverse. Scientists have named about a million insect species, but estimate that millions more remain to be named and described! A few key characteristics unite this myriad of different species. Insects have a body composed of three segments - the head, thorax and abdomen; they have six legs (three pairs) attached to the thorax; they have four sets of head appendages - one pair of antennae and three pairs of "jaws"; and they share some respiratory and excretory structures that we'll get to later. Most insects, but not all, also have wings coming out of their thorax.

Respiratory: Insects are adapted to life on land, so they breathe air. The two main components of the insect respiratory system are the **spiracles** and **tracheae**. Spiracles are small holes in the abdomen. Air enters through these holes and travels through a network of branching tubes - the tracheae - that connect right to the tissues of the body. Gases are exchanged directly with structures like muscles instead of being transported around the body in the blood. Smaller insects continually take up air (and therefore oxygen) through the spiracles. Carbon dioxide builds up and gets stored in the blood before being expelled in cyclical bursts. Larger insects breathe by closing the spiracles at the front end of their body, pushing carbon dioxide out of the back spiracles using their muscles, then opening the spiracles at the front of the body, which suck in new air like a vacuum.

Circulatory: Insects have an **open circulatory system**. Instead of being transported to different body parts through a network of closed vessels, blood is pumped by the **heart** through the **arteries** and into the body cavity, where the internal organs and body tissues bathe right in it. In other words, the body is full of freely-flowing blood! From the body cavity, blood is funneled into **veins** and back into the heart.

Insect Mouthparts



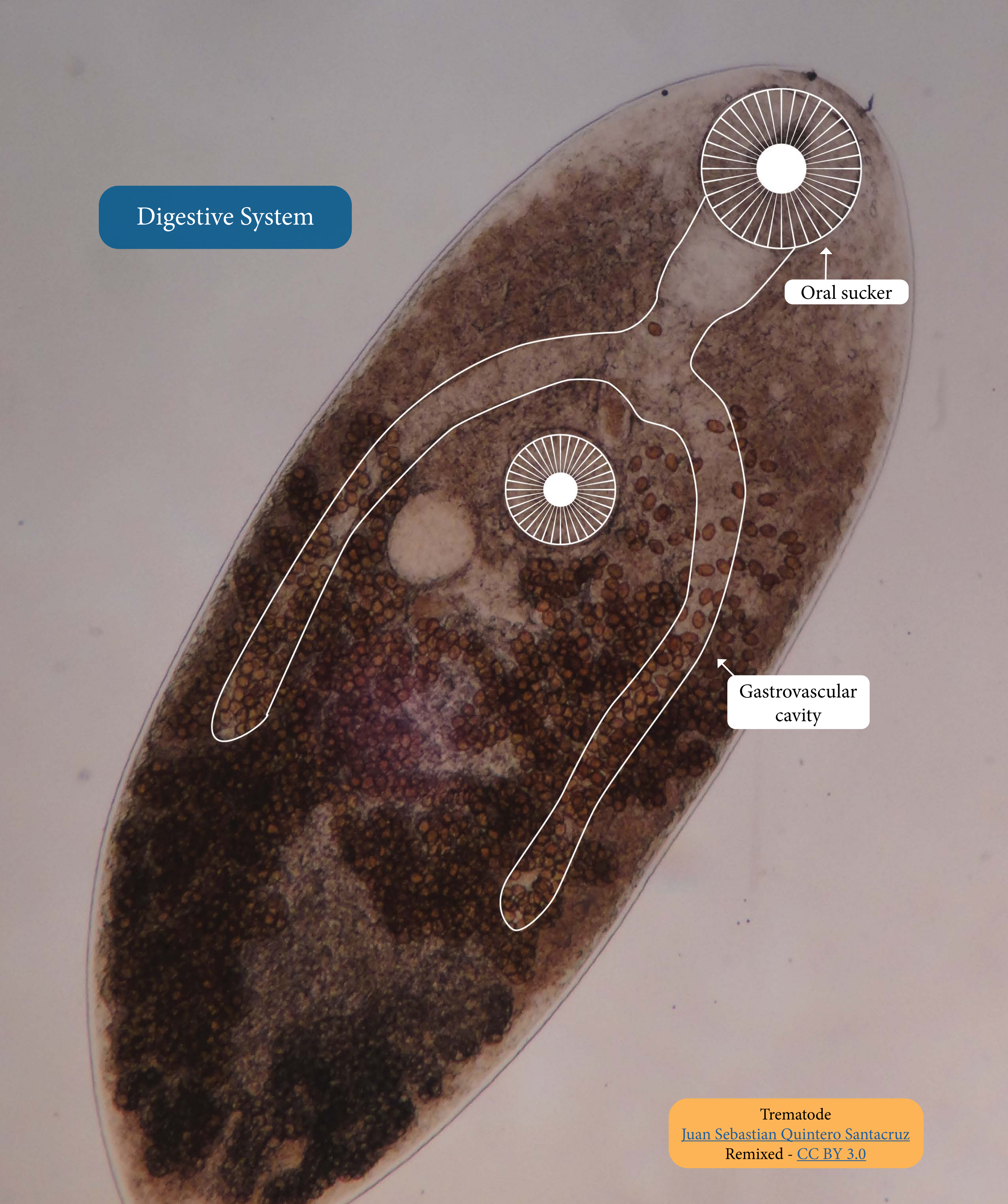
Chewing Piercing-Sucking Sponging Siphoning

Digestive: Three pairs of feeding structures ("jaws") handle food and bring it into the **mouth**. They are called the **mandibles**, the **maxillae** and the **labia**. In some insects, the mandibles are like teeth and chew up food; the maxillae hold and guide food to the mandibles, and have sensory parts that smell and taste; and the labia work like a lower lip, and are also sensory. These mouthparts are similar in function tot he jaws of vertebrates - but unlike vertebrate jaws, they are attached to the head outside of the mouth. In other insects, the mouthparts are specialized for sucking, sponging, rasping, piercing, biting and siphoning. From the mouth, food travels to the **stomach**, where it mixes with digestive chemicals that are made in the **digestive gland**. Broken-down food passes on to the **intestines**, where it is further digested and food molecules are absorbed. Undigested material (frass) passes from the intestines out through the **anus**. Some insects also have a **crop** and a **gizzard** between the mouth and stomach. The crop stores food from large meals, while the gizzard grinds food up.

Musculoskeletal: Insect bodies get their structure from a hard external skeleton - an **exoskeleton**. The exoskeleton is made up of many plates attached together by joints that allow bending. It is not made of bone, but out of a fibrous material called **chitin**. In addition to giving insect bodies structure, exoskeletons provide protection from predators and prevent water loss. Having a rigid exoskeleton, however, poses a challenge to insects. As they grow bigger and bigger, their outer covering inevitably gets too small - so they must shed and replace their exoskeleton in a process called **moulting**. Insects also rely on a system of **muscles** to move their bodies and limbs. In winged insects, the muscles power flight.

Trematodes

Digestive System



Trematode
Juan Sebastian Quintero Santacruz
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Trematodes[4,13,18]

Trematodes are a group of parasitic flatworms. **Parasitism** is a type of close interaction between species in which one - the parasite - benefits at the other's - the host's - expense. Parasites live on or inside their hosts, sapping nutrients and energy and diverting these resources away from host growth, survival and reproduction. Some parasites also change their hosts' behaviour. Trematodes usually infect two or three different hosts during their complex life cycles, jumping from one to the next at different life stages. Because they're adapted to parasitic living, their bodies and body systems are highly modified.

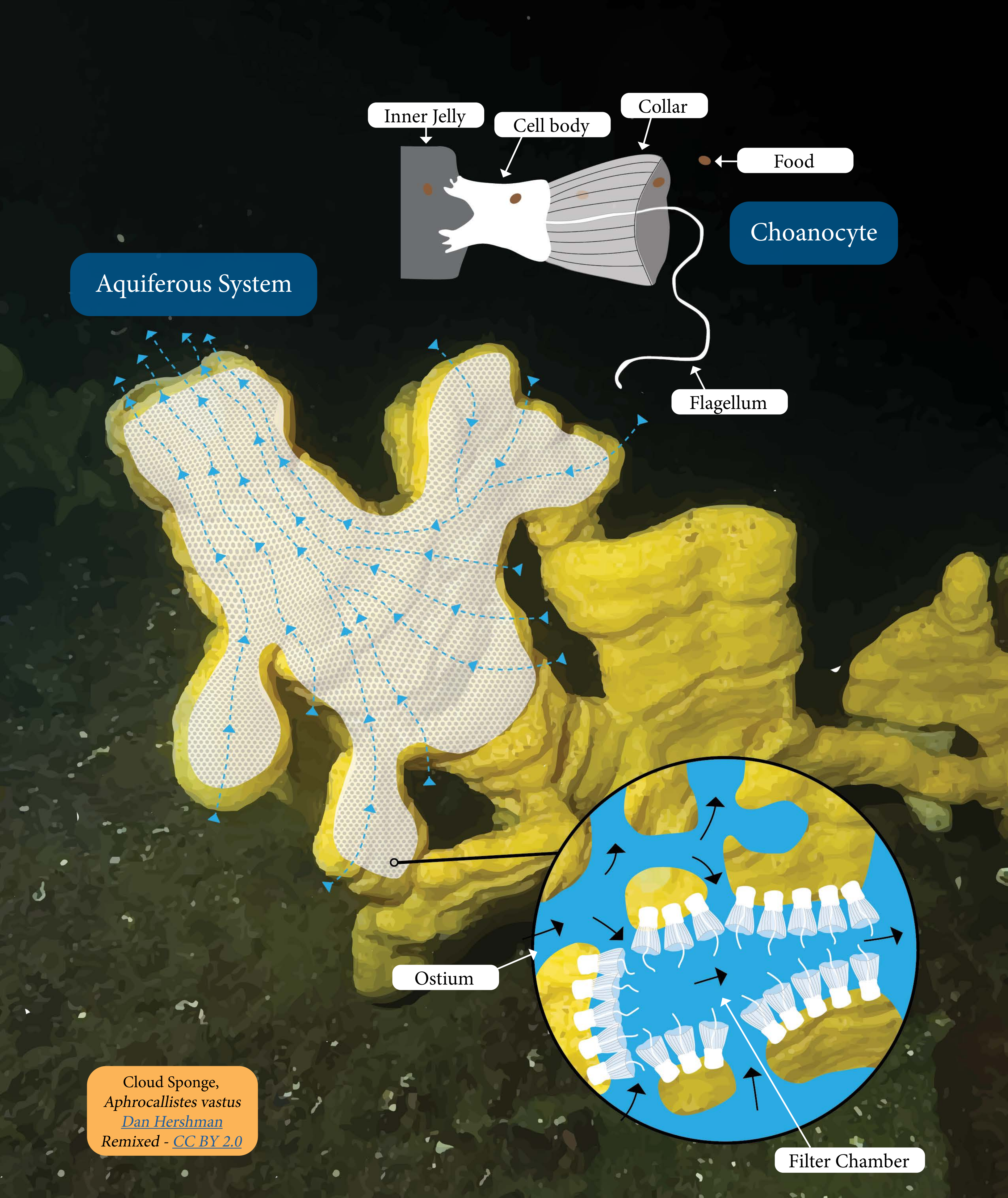
Respiratory: Trematodes don't have respiratory organs. Instead of lungs or gills, they exchange gases with the environment through the **tegument** - an outer body covering sort of like skin. Oxygen and carbon dioxide are exchanged right into and out of the body since trematodes are so small and flat.

Circulatory: Trematodes don't have circulatory organs, either! Nutrients are distributed by the digestive system instead of a circulatory system, with food molecules diffusing directly to different body parts.

Digestive: The digestive system of a trematode is made up of a bag-like space called the **gastrovascular cavity (GVC)**. The GVC is where food is digested and nutrients are absorbed. It has a single opening at the head-end for incoming food and outgoing wastes - in other words, just one opening that doubles as a mouth and an anus. A **sucker** surrounds the mouth/anus opening to latch onto the host. Some trematodes leak out substances from this sucker or the GVC that partially digest their food outside of their bodies before it's pumped inside. Trematodes that live in their hosts' digestive systems can also absorb already-broken-down food directly through their tegument.

Musculoskeletal: Trematodes don't have skeletal elements - they are soft-bodied invertebrates - but they do have **muscles** that contract and relax to move.

Sponges



Cloud Sponge,
Aphrocallistes vastus
Dan Hershman
Remixed - CC BY 2.0

Sponges[2,4,13,18]

These odd, non-moving creatures were thought to be plants by early biologists. In fact, they are members of the animal kingdom! Sponges rank among the most ancient animals on Earth, and have some of the most basal animal characteristics. The sponges biologists study aren't the household cleaner-uppers you have in your kitchen - most of the sponges people buy today are synthetic - but a group of mostly marine creatures with a distinctive way of life. Sponges' bodies are built around a network of internal passageways called the **aquiferous system**. The aquiferous system is made up of pores, channels and chambers, through which water flows. The aquiferous system does many of the things our different body systems do - not with tissues and organs, but with water and special cells called **choanocytes**.

Respiratory: Choanocytes have a **flagellum**. Flagella are long, flexible "hairs" that some cells use to move themselves or fluids; for example, sperm cells swim using flagella. When choanocyte flagella beat back and forth, they create a current that brings water through openings in the sponge's exterior, into the aquiferous system, through the sponge's body and out through an opening at its top. Gases are exchanged between the water and the choanocytes as water circulates in, through and out of the sponge.

Circulatory: The movement of water through the aquiferous system circulates gases, wastes and food through the sponge like a circulatory system would - no need for blood or vessels!

Digestive: Choanocytes also have a **collar**. The collar traps food particles from the water and moves them toward the cell body, where they're taken up and eaten or passed on to other cells that live in the jelly-like interior of the sponge.

Musculoskeletal: Sponges get their structure from internal skeletal elements like **spicules** and **spongin**. Spicules are made of silica (glass) and calcium carbonate (like seashells). They take on a variety of shapes, from six-sided stars to cubes to small spiky balls. In addition to giving sponges shape, the pointy spicules are useful in defense against predators. Spongin is made of rubbery proteins that lend structure to sponges, but aren't useful in defense.

Please remember that…

Animals that are less “complex” than others are not “worse.” Sponges have no tissues or organs, but have found success for hundreds of millions of years. There are tens of thousands of species of trematodes - many are human parasites! Insects are one of the most diverse groups of animals on Earth. And echinoderms bodies are streamlined to the point where water does many of the things our more “complex” tissues, organs and systems do.

Vertebrate animals (like us) are incredible. We are the product of billions of years of evolution. But our complex body systems do not make us better than other creatures. Each organism has a place in the world’s ecosystems - just because that place isn’t similar to our own doesn’t make it any less valuable.

Animals and the tree of life

Animals are only one branch on the tree of life. Plants, fungi and different groups of protists, bacteria and archaea fill out the rest of the tree. Like animals, all of these organisms fulfill the basic processes of life - they just do it a little differently.

Plants[1]**:** transform carbon dioxide, water and sunlight into energy. They don't need to eat food - they make it themselves! The parts of the plant that are above the ground (the **stem** and **leaves**) take up carbon dioxide and sunlight; the parts below ground (the **roots**) collect water and other minerals. A system of tubes called **xylem** and **phloem** transport substances through the body. Materials in the **cell walls** (cellulose and lignin) give plants their structure.

Fungi[20]**:** get their energy by "eating" other organisms. A typical fungus releases digestive chemicals onto a food source and absorbs food molecules using its **hyphae** - thin filaments that make up the fungal body. Like plants, materials in the **cell walls** (chitin) give fungi their structure.

Protists[2]**:** are a large, incredibly diverse group of organisms. Some get their energy by engulfing food into their cell bodies; some break down dead material; some harvest energy from sunlight; and some divert nutrients away from other living things. Gases are exchanged directly between protists and their environments. Depending on the species, protists support their bodies in different ways. Diatoms, for example, are surrounded by a hard cell wall made of glass. Other protists, like amoebas, have little structural support and are constantly changing body shape.

Bacteria[2,21]**:** get their energy from sunlight, from chemical reactions or by eating other organisms, depending on the species. **Archaea**[2,21]**:** also make and use energy in a variety of ways - including by breaking substances down to produce methane and by consuming sulphur. Like protists, gases are exchanged directly between bacteria and archaea and their environments. Despite their similarities, Bacteria and Archaea are very different groups of organisms. This highlights that this less complex way of life is still extremely successful, over hundreds of millions of years!

The Tree of Life

Additional Activites and Resources

GIF comparing breathing in humans, birds and grasshoppers:

vox.com/xpress/2014/10/27/7078297/breathing-gif

In humans, notice:

- The muscles pulling and expanding the lungs to take air in
- The flow of air into the lungs only during the inhale (breath in)
- The network of blood vessels surrounding the alveoli

In birds, notice:

- The air sacs at the back end of the body filling up with oxygenated air, the air sacs at the front of the body filling up with deoxygenated air
- The flow of air into the lungs during both the inhale and exhale (breath in and out)
- The structure of the parabronchi of the lungs (straight lines up/down and across) and the blood vessels underneath (network of branching vessels)

In grasshoppers, notice:

- The network of branching tracheae
- How the respiratory system isn't limited to the chest (as in humans and birds), but extends throughout the entire body
- The flow of oxygenated air into the front spiracles while the back spiracles are closed off; the flow of deoxygenated air out of the back spiracles while the front spiracles

Additional Activites and Resources

Video explaining how sea stars move using their tube feet:
youtube.com/watch?v=9rxf_2EgwfE&t=135s

Video showing the different adaptations of insect mouthparts (mandibles, maxillae, labia):
youtube.com/watch?v=BvLolPN8NvU

Written by Jamie Clarke

Designed by Evan Craig

References

1) BIOL 260 lecture slides

2) Hine, R. 2019. A Dictionary of Biology (8th ed.). Oxford University Press USA - OSO.

3) toxtutor.nlm.nih.gov/08-003.html

4)BIOL 204 lab book

5) BIOL 204 lecture slides

6) britannica.com/animal/mammal/Digestive-systemt

7) britannica.com/science/vertebral-column

8) allaboutbirds.org/news/do-all-birds-have-gizzards/#:~:text=Birds%20with%20thick%20gizzards%20frequently,%2C%20sand%2C%20and%20small%20shells.&text=All%20birds%20do%20have%20a,small%20and%20thin%2Dwalled%20gizzard

9) britannica.com/science/cloaca

10) BIOL 427 lecture slides

11) burkemuseum.org/collections-and-research/biology/herpetology/all-about-amphibians/all-about-amphibians

12) britannica.com/animal/fish/The-respiratory-system

13) Brusca, RC and Brusca, GJ. 2003. Invertebrates (2nd ed.). Sinauer Associates.

14) askabiologist.asu.edu/tube-feet

15) Harbo, RM. 2011. Whelks to Whales: Coastal Marine Life of the Pacific Northwest (2nd ed.). Harbour Publishing, BC.

16) Resh, VH and Cardé, RT. 2009. Encyclopedia of Insects (2nd ed.). Elsevier/Academic Press.Northwest (2nd ed.). Harbour Publishing, BC.

17) BIOL 327 lecture slides

References

18) BIOL 205 lecture notes

19) britannica.com/animal/gastropod/The-foot

20) section of a textbook on plants, given out as course material for BIOL 323 (Chapter 14: Fungi)

21) open.oregonstate.education/generalmicrobiology/chapter/archaea/