Lab Objectives
1. To learn how the divisions of the circulatory system relate to one another.
2. To understand how blood flows through a single circuit circulation with gills.
3. To learn which vessels supply and drain different organs and areas of the body.
4. To understand how blood flows through the heart of the shark.

Material to Learn
Shark circulation
- Figures 3.27, 3.28, 3.29, 3.30, 3.31, 3.32 (only hepatic portal system)
- Demo: Fish Heart.
- Omit the veins, except for common cardinal v. and the hepatic portal vv. (yellow)

Background & Instructions
During this week’s lab, you will be dissecting and studying the shark’s circulatory system. The heart and anterior portion requires some dissection, while the posterior portion requires careful observation and working out the 3-D arrangement of the vessels. The shark is a great example of a single circuit circulatory system, where blood passes through the heart only once per cycle through the body. Blood vessels can be highly variable between individuals: although all

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Term list
Anterior intestinal a.  Gastric a.  Posterior intestinal a.
Anterior intestinal v.  Gastric v.  Posterior intestinal v.
Anterior ventrolateral a.  Gonadal a. (ovarian or testicular)  Posttrematic branch
Atrium  Hepatic a.  Pretrematic branch
Celiac a.  Hepatic portal v.  Sinus venosus
Collector loop  Hyoidean a.  Stapedial a.
Conus arteriosus  Internal carotid a.  Ventral aorta
Cross trunk  Lienomesenteric v.  Ventricle
Dorsal aorta  Paired dorsal aortae  Pancreaticomesenteric a.
individuals typically have the same vessels, the junctions between vessels vary. The best way to learn the vessels is to learn what each vessel supplies blood to or drains, and to learn the order in which vessels branch off one another. A good way to proceed is to start centrally with big vessels (start at the heart, or with dorsal or ventral aorta) and to work peripherally.

1. **Dissecting instructions**

1. **Start with the branchial region and the heart.** You will not be exposing the heart as shown in Figure 3.27. Instead, you will be accessing it from the dorsal/internal side. In a previous lab, you cut through the gills on one side. Reflect the lower jaw to open up the pharyngeal region and try to flatten it out. You may need to break some of the cartilage in the uncut gill arches to do this. Use blunt probes or pins to keep the pharyngeal region open. Do this by placing a probe/pin through the spiracle on the cut side, and another one through the thin tissue anterolateral to the tongue, also on the cut side. You should now be looking at the roof and floor of the buccal cavity, as shown in Figure 3.22.

2. **Skin the roof and floor of the buccal cavity, and the gill arches to reveal the underlying vessels.** On the dorsal side, you may need to clean some fascia beneath the skin to reveal the vessels. This should be fairly straightforward, but be careful not to rip through the vessels. Follow the efferent branchial aa. into the gill arches. Remove the ceratobranchial cartilages from the gill arches as needed to expose the collector loops with their pre- and posttrematic branches, as seen in Figure 3.30.

3. **Now turn your attention to the floor of the buccal cavity.** Note that there is a cartilaginous plate medially and slightly posterior to the gill arches. Use the curved forceps to break through this, slipping a blade underneath and pulling up toward you. Remove cartilage to expose the heart. Note that the heart, ventral aorta and afferent branchial aa. are NOT injected with latex. This means that they are very fragile and easily damaged. Uncover them by removing cartilage and muscle.

4. **Once you have identified all of the vessels in the anterior region of the shark, turn your attention to the posterior – the abdominal cavity.** Most of the other vessels require little or no dissection. Study and learn them. The best way to do this is to start with large vessels and follow the flow of blood to smaller ones. Start with the dorsal aorta and follow it posteriorly, noting all of its branches. Then follow each branch, identifying as you go. Use the tips given in other parts of this lab.

2. **Divisions of the circulatory system**

Always think about the direction that blood is flowing in vessels as you learn them. In your shark, the vessels are color-coded because they have been injected with colored latex. **Arteries are colored red,** and always take blood away from the heart and towards capillary beds of tissues. **Veins are colored blue,** and always take blood back to the heart. Arteries and veins are NOT defined by whether blood inside them is oxygenated or deoxygenated, but whether it is travelling toward or away from the heart.

Your shark also has blood vessels that are colored **yellow; these vessels make up the hepatic portal system.** The hepatic portal system carries blood from the viscera to the liver. Its main function is to take nutrients and other digested molecules from the viscera to get detoxified by the liver. The hepatic portal system ensures that all blood that has absorbed nutrients and toxins from the digestive system goes to the liver. One possibly confusing aspect of this is that the liver is
both supplied by blood from the hepatic portal system (this is nutrient rich but oxygen poor), and by blood from the arterial system (this is nutrient and oxygen rich). Hence, the hepatic a. supplies oxygenated blood that is nutrient rich and detoxified from previously going through the liver, and the hepatic portal v. supplies oxygen poor, nutrient rich blood to the liver for detoxification. All blood leaves the liver via the hepatic v. Note that you only have to know the hepatic portal veins, and not the regular (blue) veins, with the exception of the common cardinal v., which brings blood back to the heart.

The arterial, venous, and hepatic portal systems are separated from one another by capillary beds. Arteries supply blood to tissue capillaries and veins drain blood from tissue capillaries. In the case of the viscera, arteries take blood to their capillaries, and the hepatic portal system takes blood away from visceral capillaries. One exception to these general rules happens at the gills. The gills have capillaries with arteries on both sides.

To sum up, when studying the vessels, think about the following for each vessel:

- Is the vessel artery, vein, or hepatic portal?
- Is the vessel taking blood to the heart or away from the heart?
- Is blood inside the vessel oxygenated or deoxygenated?
- Is blood inside the vessel nutrient rich or nutrient poor?
- What is the vessel supplying blood to or draining blood from? This can help you remember vessel names.

You can use the answers to these questions to figure out a great deal about a vessel. For example, the anterior leinogastric v. drains blood from the spleen (leino~) and the stomach (gastr~), and so is a hepatic portal vein. This means that it is nutrient rich, oxygen poor, and is on its way to the heart via the liver.

What are the four chambers of a shark’s heart, and in what sequence does blood flow through them?

What is the cartilaginous element that you had to break and remove to expose the heart?

Why do you think that many parts of the venous system in the shark are not vessels, but sinuses? Why don’t we humans have similar sinuses?
Is blood in the following vessels oxygen rich or poor? Nutrient rich or poor?

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Amount of Oxygen</th>
<th>Amount of Nutrients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conus arteriosus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Efferent branchial a.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal carotid a.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iliac a.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gastrosplenic a.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posterior intestinal v.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gastric v.</td>
<td></td>
<td></td>
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<tr>
<td>Hepatic portal v.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common cardinal v.</td>
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</tr>
</tbody>
</table>

Name the vessel that is supplying blood to and the vessel that is draining each of the following structures.

<table>
<thead>
<tr>
<th>Supplying Blood</th>
<th>Structure</th>
<th>Draining Blood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conus arteriosus</td>
<td>Chondrocranium</td>
<td>XXX</td>
</tr>
<tr>
<td></td>
<td>Gill lamellae</td>
<td>XXX</td>
</tr>
<tr>
<td></td>
<td>Pectoral fin</td>
<td>XXX</td>
</tr>
<tr>
<td></td>
<td>Gonad</td>
<td>XXX</td>
</tr>
<tr>
<td></td>
<td>Body of Stomach</td>
<td>XXX</td>
</tr>
<tr>
<td></td>
<td>Spleen</td>
<td>XXX</td>
</tr>
<tr>
<td></td>
<td>Liver</td>
<td>XXX</td>
</tr>
<tr>
<td></td>
<td>Posterior end of spiral valve</td>
<td></td>
</tr>
</tbody>
</table>
If you are a blood cell in the atrium of the heart and you flow through vessels to the dorsal aorta, list all of the circulatory structures that you pass through. If you pass through a capillary bed, state that and the structure in which the capillary bed is.

Atrium →

If you are a blood cell in the common cardinal vein and you flow through vessels to the hepatic portal vein, list all of the circulatory structures that you pass through. If you pass through a capillary bed, state that and the structure in which the capillary bed is. Notice that this question requires that blood flows through the heart and gills. This means that your answer to the previous question is a substantial part of the answer to this question!

Common cardinal v. →

Study exercise: Make a flowchart with all of the blood vessels that you need to learn in the shark and drawing arrows between them. Learning this flowchart will teach you most of what you need to know about circulation in the shark. Do this on an extra sheet of paper and attach it to this worksheet. Bring it to the next lab as part of this worksheet.