FLUID DYNAMICS

BLOOD PRESSURE
The purpose of any heart is to generate the force necessary to propel blood through the circulatory system. The blood PRESSURE produced when the heart contracts is the primary generator of this propulsive force. It is technically difficult to directly measure the pressure produced by a beating heart. A reasonably accurate substitute, however, is to measure MEAN PRESSURE or MEAN ARTERIAL PRESSURE.

1. In your own words, what is mean arterial pressure (MAP)?

This measure of blood pressure is what we will use in this course when talking about blood pressure so it’s an important concept to understand. Your book has a fairly long discussion about how and why MAP is an oversimplification of the actual situation in circulatory systems. For our purposes, oversimplification is fine; if you go on to medical or veterinary school, you’ll learn about the complexities then.

CARDIAC OUTPUT

2. In your own words, what is the definition of cardiac output (CO)?

3. Which of the following could be units of cardiac output?
   - L/min
   - beats/minute
   - ml/hour
   - Liters

4. What two features of heart structure and function combine to determine cardiac output?

VASCULAR RESISTANCE

The amount of pressure a heart must generate depends on the amount of resistance given by all the vessels in the system. This is termed VASCULAR RESISTANCE or TOTAL PERIPHERAL RESISTANCE (TPR).

5. What is the relationship between resistance to flow and vessel diameter? Answer this question either in words or in “math”.

FLOW VELOCITY and FLOW RATE

6. What is the difference between flow velocity and flow rate? Hint: what are the units of each?
CIRCULATORY SYSTEMS

7. Are the following statements TRUE or FALSE? Correct any false statements to make them true.
   a. All vertebrates have closed circulatory systems. TRUE / FALSE
   b. All invertebrates have open circulatory systems. TRUE / FALSE

In this class we will focus on closed circulatory systems.

8. Compare and contrast the vessels making up the arterial, venous, and capillary systems in terms of wall thickness and composition (i.e., what it is made with and/or its structure). A list of differences would work well here.

9. Which blood vessels are primarily responsible for regulating flow through a closed circulatory system?
   ARTERIES  ARTERIOLES  CAPILLARIES  VENULES  VEINS

INTEGRATING FLUID DYNAMICS WITH CLOSED CIRCULATORY SYSTEMS

10. What is the functional significance of the relationship between total cross-sectional area and average linear velocity shown in Figure 23.12a given what you know about the functions of the arterial, venous, and capillary systems.

11. Please explain why average blood pressure decreases as one moves from the large arteries to the large veins (Figure 23.12b).

Cardiac output (CO), total peripheral resistance (TPR), and mean arterial pressure (MAP) are all interdependent and can be related with the following equation:

   \[ CO = \frac{MAP}{TPR} \]

A main goal of circulatory physiology and regulation is to keep MAP as constant and low as possible to ensure adequate \( O_2 \) delivery to tissues. Keeping MAP as low as possible is important to minimize the amount of strain placed on the heart. By contrast, CO will vary with activity, stress, and basically anything that alters the amount of energy an animal uses.

12. When you jog your CO increases to ensure adequate \( O_2 \) delivery to your working muscles.
   a. What element of your circulation changes to maintain your MAP as constant and as low as possible during this time of increased CO (Hint: look at the equation)?
   b. Based on the material in Chapter 23, provide at least one plausible mechanism behind the change described in 12a.
COMPARATIVE ASPECTS OF VERTEBRATE CIRCULATORY SYSTEMS

Highly schematic diagrams of the circulatory systems of the major classes of vertebrates are shown on the next page. As shown in these diagrams and described in your text, there are two main trends in the evolution of vertebrate circulatory systems:

- Single circuit (systemic and respiratory tissues in the same “loop”) \(\Rightarrow\) double circuit (systemic and respiratory loops)
- Heart with 1 atrium and 1 ventricle \(\Rightarrow\) heart with 2 atria and 1 ventricle \(\Rightarrow\) heart with 2 atria and incompletely divided ventricle \(\Rightarrow\) heart with 2 atria and 2 ventricles.

13. Use arrows to indicate the direction of blood flow on each schematic.

14. Which vertebrate classes have ... (study the schematics and your text carefully; some single circuit systems may appear to have more than one loop)
   a. single circuit systems
   b. double circuit systems

15. What are two potential functional limitations of single circuit systems relative to double circuit systems?

16. Which vertebrate classes have hearts with:
   a. 1 atrium and 1 ventricle
   b. 2 atria and 1 ventricle
   c. 2 atria and an incompletely divided ventricle
   d. 2 atria and 2 structurally divided ventricles

17. Mammals and birds maintain high blood pressures in their systemic circuit and low pressures in their pulmonary circuit. Why is a high-pressure systemic circuit important for these animals? Why is a low-pressure pulmonary circuit important? Complete answers should include the structural basis for “why” as well as the physiological reasons for “why”.

18. Although we tend to think of the completely divided 4-chambered hearts and double circuit systems of birds and mammals as “better” than the incompletely divided hearts and circuits of reptiles and amphibians, there is obviously something beneficial about incomplete separation or it would have been eliminated by natural selection long ago. Describe a situation where incomplete structural separation of the pulmonary and systemic circuits might provide an advantage over complete separation.
Animal Physiology
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= Respiratory structure
= Tissues (e.g., muscle, liver, brain, etc.)
= Heart
Ventricular end
Atrial end

= vessels with high O2 content
= vessels with low O2 content

FISH

AMPHIBIAN (FROG)

Skin

Lungs