

# LAB 3

## The Heart as a Pump Exercise

### Assignments:

***Due at the beginning of lab:***

**Quiz:** Pre-lab for Heart as a Pump (pages 25 – 27) and IP exercise on Cardiac Output (page 34)

***During the lab period:***

Complete the worksheets in today's lab concerning heart rate, stroke volume and cardiac output (pgs. 29-33).

***In Class Exercise:***

Understanding Heart Rate and Stroke Volume using the Heart Pump Setup

**NEXT LAB:** Quiz over Blood Pressure Terms (pg 36) and IP Exercises (Pgs 46-47).

## **The Heart as a Pump – Pre-lab Exercise**

**Introduction – Read this section before you come to lab and be prepared for a quiz.**

The heart is made of two unusual and sophisticated pumps that work in synchrony. Like most pumps, they can deliver varying amounts of fluid depending upon the needs of the system they supply. During the lab exercise you will explore the two ways that the output of a pump can be increased or decreased using a simple physical model which reproduces most of the important features of the cardiac cycle: **cardiac output, stroke volume and heart rate.**

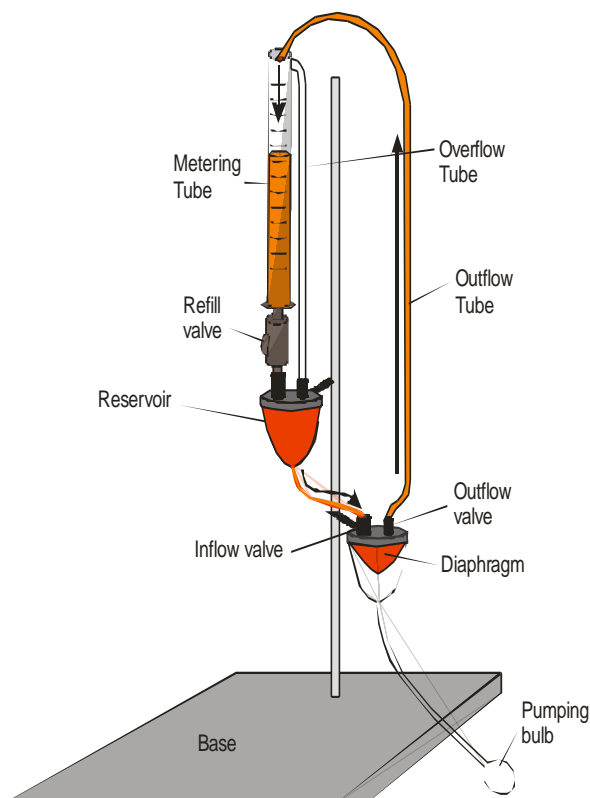
Cardiac output is the amount of blood pumped in one minute (ml/min). It is the product of stroke volume (ml/beat) and heart rate (bpm).

$$CO = SV \times HR$$

During the lab you will use the heart model shown in **Fig. 1**. Important functions of the heart are reproduced by the **diaphragm - the ventricle.**

Fluid flows through the system in the direction of the arrows. The diaphragm fills with fluid coming from one source (the **reservoir - the atria**). When the pumping bulb is squeezed the fluid flows in one direction through the outflow tube into the metering tube. The volume in the metering tube after one pump is equal to **SV**.

This directional flow happens only because there are two **check valves - the heart valves** on the pump lid where the tubes connect. A check valve is a structure that allows flow in only one direction.



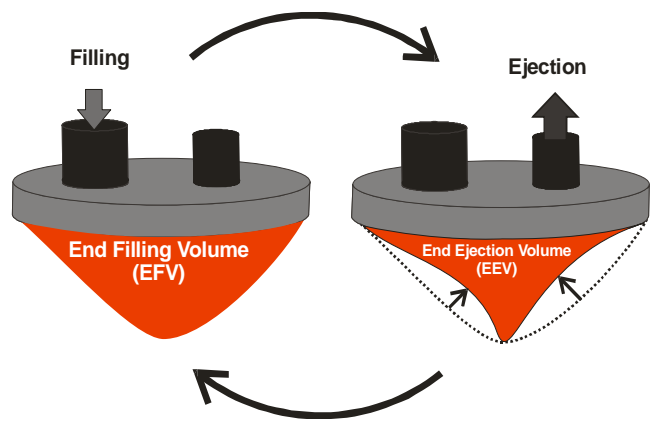
**Fig. 1.** Heart pump setup

When the pump fills with fluid and then ejects it repeatedly, the water in the reservoir is gradually pumped into the metering tube. One fluid **filling period (diastole)** followed by one **ejection period (systole)** of the

diaphragm constitutes one **pumping cycle - cardiac cycle** as illustrated in Fig 2.

**NOTE: EFV = EDV and EEV = ESV**

It is very important also to determine the volume of fluid pumped with each cardiac cycle called the **Stroke Volume (SV)**.



**Fig. 2. Pumping cycle – Cardiac cycle**

In **Fig. 3** the volumes in the metering tube before (0 ml) and after 60 seconds (200 ml) of pumping are shown.

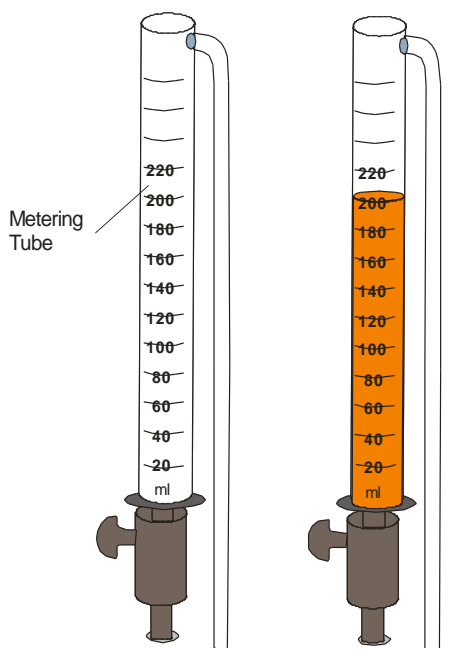
**If there are 10 pumping cycles (heart beats) in 60 seconds, what is stroke volume?**

\_\_\_\_\_

The **End diastolic volume (EDV)** is the amount of fluid in the diaphragm (ventricle) immediately before it is compressed.

The volume left inside the diaphragm (ventricle) after ejection (stroke volume) is called the **End systolic volume (ESV)**.

**If EDV = 100 ml and ESV = 60 ml, what is SV?** \_\_\_\_\_



**Fig. 3. Volume Ejected in 60 seconds**

The fraction (percentage) of the EDV that is pumped out in one cycle is called the **Ejection Fraction (EF)**, and is calculated as follows:

**EF = (SV / EDV) X 100**

**What would be the value of EF in the previous question?** \_\_\_\_\_

**Look up and define the terms.**

Relaxation and filling period:

Contraction and ejection period:

SV:

EDV:

ESV:

EF:

HR:

CO:

Using your textbook, define Contractility:

## Start Here for *Heart as a Pump* Lab

The most effective way to carry out the activities in this lab is for each member of your group to have a clearly defined role. **Before you begin your first activity assign the roles of your group members.**

- 1. Reader/Coordinator** : keeps your group on task by carefully reading the instructions and checking them off as each task is accomplished.
- 2. Information Gatherer/Timer**: seeks help from the lab instructor and times experiments.
- 3. Recorder/Reporter**: keeps careful records of all data and transfers it to other group members; he/ she reports results to the class.
- 4. Instrument operator(s)**: sets up equipment and carries out operations of the experiment.

**Identify all of the labeled parts of the pump model as shown in Figure 1 on the previous page, and see how it works.**

### ***Practice:***

1. Empty the metering tube by opening the reset valve and then close the refill valve.
2. Squeeze the pumping bulb until it is totally closed and keep it squeezed.
3. How much fluid was pumped with one squeeze? \_\_\_\_\_ml.

What would this volume ejected from the heart be called?

\_\_\_\_\_

### **Protocol I: 5 second intervals (HR = 12)**

4. Beginning with your first "pump" at 5 seconds past the top of the minute, how many cycles will be completed in one minute? \_\_\_\_\_
5. What is the pumping rate – heart rate (HR) that you will maintain: \_\_\_\_\_ bpm
6. Pump every 5 seconds and complete the table.

<b>Trial 1</b>												
<u>Pumping Cycle</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>	<u>9</u>	<u>10</u>	<u>11</u>	<u>12</u>
<u>Meter Tube Volume ( 4 ml)</u>												
<u>SV (ml)</u>												

7. For the first pump only, subtract the volume in the tube from the volume that was in the tube before you started (4 ml).
8. After that, calculate SV for each cycle by subtracting each metering tube volume from the previous one.
9. Determine the average SV (add all the volumes and divide by 12). \_\_\_\_\_
10. Determine CO by reading the total volume collected in the metering tube. (Volume in pumping cycle 12 less 4 ml – the volume you started with.)  
\_\_\_\_\_ (Put this value in the Table 1, trial 1.)

<b><u>Table 1</u></b>	<b><u>Trial 1</u></b>	<b><u>Trial 2</u></b>	<b><u>Average</u></b>
<b><u>HR (BPM)</u></b>	<u>12</u>	<u>12</u>	<u>12</u>
<b><u>CO (ml/min)</u></b>			
<b><u>SV (ml)</u></b>			

11. Calculate SV: ( $SV = CO \div HR$ ) \_\_\_\_\_  
How does your calculated average SV compare to the actual SV in question 9?
12. Repeat the experiment one more time, but from now on only record the final CO, not the volume for each pumping cycle. Calculate SV and record your values in the table, trial 2.
13. Calculate the average CO and SV for protocol I and place values in the table.

## **Protocol II: 2 second intervals (HR = 30).**

Repeat the experiment as in Protocol I above, but this time use a 2-second interval.

1. Beginning with your first "pump" at 2 seconds past the top of the minute, how many cycles will be completed in one minute? \_\_\_\_\_
2. What is the pumping rate – heart rate (HR) that you will maintain: \_\_\_\_\_ bpm
3. Compare this HR to the HR in Protocol I. Based on this comparison, what would you expect the CO will be? \_\_\_\_\_ ml/min
4. Empty the metering tube and operate the pump as before, only this time pump every 2 seconds for 30 seconds.

**\*\*\*\*Instead of pumping for 60 seconds we will only pump for 30 seconds and double to volume to record in ml/min.**

5. **What was the CO:** \_\_\_\_\_ **ml/min** (Remember to double the measured volume to make it equal to a minute of pumping and enter the result in Table 2.)
6. **Calculate the average SV** and enter the result in Table 2.
7. Repeat the experiment one more time. Then calculate the SV for each trial and finally, compute the average HR, CO and SV.

Table 2	Trial 1	Trial 2	Average
<b>HR (BPM)</b>	30	30	30
<b>CO (ml/min)</b>			
<b>SV (ml)</b>			

### **Protocol III: Pumping as fast as possible.**

Heart Rates must exceed 160 bpm!

1. Predict the CO you will achieve by pumping as fast as possible. Explain your reasoning.

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2. Repeat the experiment as in Protocol II above, but this time pump as rapidly as you can for 30 seconds. Keep track of the number of pumps! Again, double your volume so the data may be expressed in ml/min. Record you data in Table 3.
3. Repeat the experiment one more time and record your data in Table 3. Then calculate the SV for each trial and finally, compute the average HR, CO and SV.

<b>Table 3. Pumping fast</b>			
	<b>Trial 1</b>	<b>Trial 2</b>	<b>Average</b>
<b>HR (BPM)</b>			
<b>CO (ml/min)</b>			
<b>SV (ml)</b>			



**Protocol IV:**

1. Transfer the average values from each of the three protocols into Table 4.

	<b>Table 1</b>	<b>Table 2</b>	<b>Table 3</b>
<b>HR (BPM)</b>	12	30	
<b>CO (ml/min)</b>			
<b>SV (ml)</b>			

2. Explain in your own words how increasing HR affects CO:

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3. Explain the relationship between HR and SV:

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4. What other changes besides HR would increase CO?

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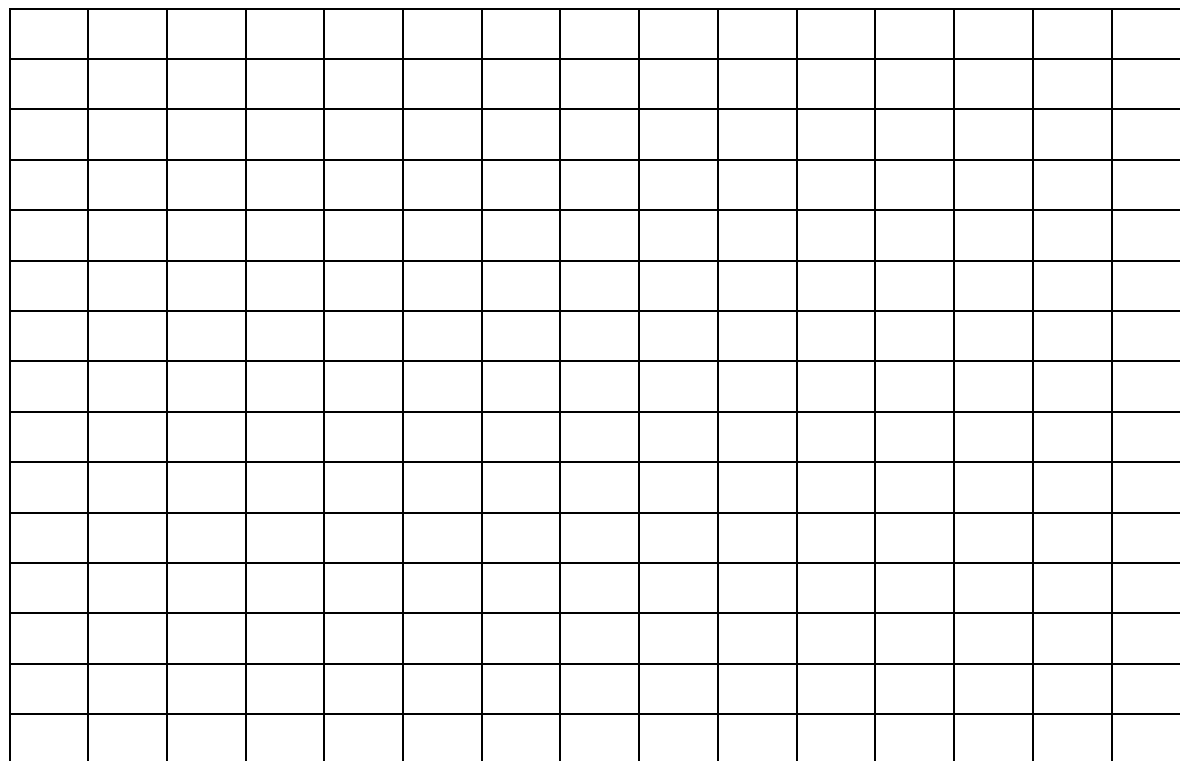
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5. Graph your results on the next page using the averages from Table 4.

Graph your results

Y axis: **Stroke Volume**

X axis: **Heart Rate**



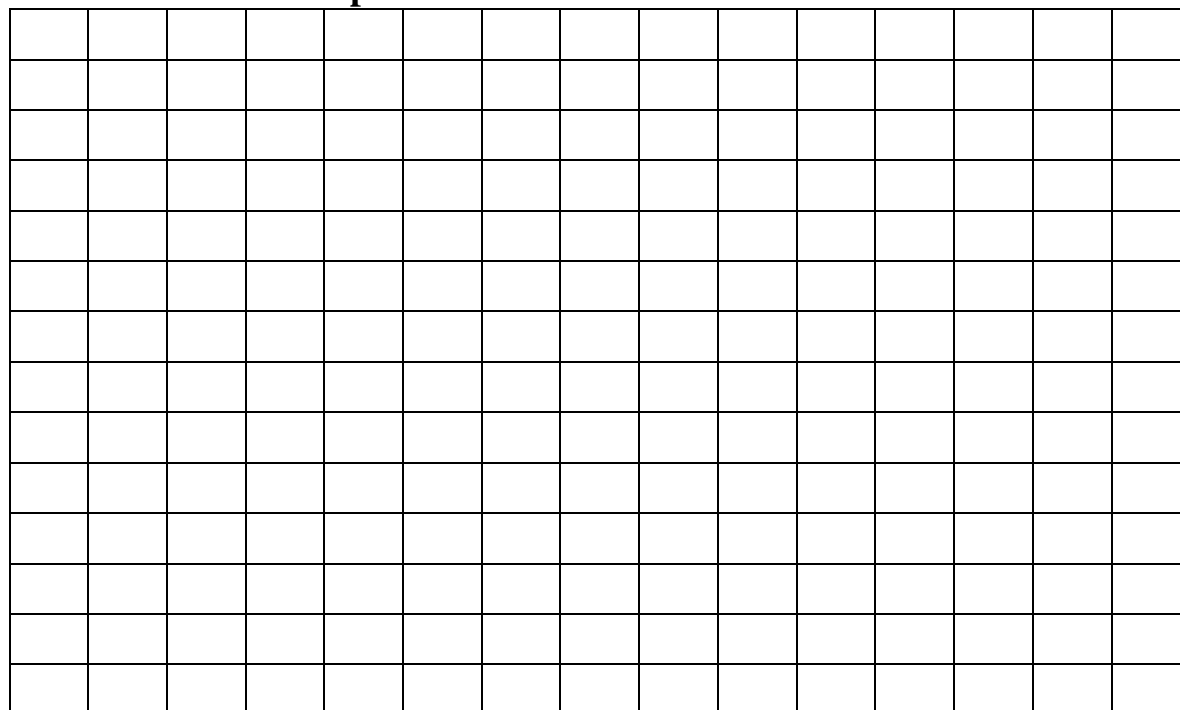
12

30

FAST

Y axis: **Cardiac Output**

X Axis: **Heart Rate**



12

30

FAST

## Cardiovascular System – Cardiac Output (Lab 3)

View “Cardiac Output” in Mastering A&P and answer the following questions:  
(Mastering A&P> study area>A&P Fix>Interactive Physiology> IP2:Cardiac Output)

1. Define Cardiac Output (CO):
  
2. Write the equation for CO:
  
3. Define Stroke Volume (SV):
  
4. Write the equation for SV:
  
5. Write the normal values (include correct units) for the following:
 

a. HR =	c. EDV =
b. SV =	d. ESV =
  
6. Given the values above, calculate CO and SV (use correct units):
 

CO =

SV =
  
7. How do the sympathetic (SNS) and parasympathetic (PNS) nervous systems affect HR?
 

SNS → \_\_\_ HR                      PNS → \_\_\_ HR
  
8. Name the 3 factors that affect SV and how they alter it ( ↑ or ↓):
  1. \_\_\_\_\_ → \_\_\_ SV
  2. \_\_\_\_\_ → \_\_\_ SV
  3. \_\_\_\_\_ → \_\_\_ SV
  
9. A \_\_\_ in HR → ↑ in ventricular filling time → \_\_\_ in venous return (VR) → \_\_\_ EDV → \_\_\_ SV This explains which factor in #8? \_\_\_\_\_
  
10. An ↑ in the SNS will \_\_\_ Contractility. This increases SV by: ( ↑ or ↓) \_\_\_\_\_ in (EDV or ESV)
  
11. What condition would ↑ aortic pressure thus ↓ ing SV? \_\_\_\_\_ This explains which factor in #8? \_\_\_\_\_