Biology 347 General Physiology Lab
Human Diving Response

Objectives

- Students will measure the heart and breathing rates of a subject at rest.
- Students will measure the heart and breathing rates of a subject during apnea (breath holding).
- Students will measure the effects of temperature on the human dive response.
- Students will measure the effects of facial wetting on the human dive response.
- Students will compare the effects of apneic and non-apneic conditions on the human dive response.

Introduction

Some air-breathing animals have developed physiological and biochemical mechanisms that allow them to survive while submerged underwater for long periods of time. These animals still get oxygen from air, but they use oxygen in a more efficient manner.

Different species have different diving capacities; but, the solutions to the problems associated with diving are similar. An animal can extend diving time by: using stored oxygen; decreasing oxygen consumption; using anaerobic metabolism; and, using aquatic respiration, if possible.

A prominent way to conserve oxygen, while diving, is selective peripheral vasoconstriction. This insures that oxygen is delivered to high priority organs like the brain, heart, and adrenal glands. The remaining organs subsist on local stores of oxygen or use anaerobic metabolism. Since vasoconstriction causes an increase in peripheral resistance, cardiac output must be reduced to maintain a normal level of blood pressure in the animal. The reduction in cardiac output is usually attained through a decrease in heart rate (bradycardia).

Diving vertebrates like alligators, birds, seals, and whales exhibit this diving reflex (bradycardia and selective vasoconstriction). Some humans also exhibit a diving reflex, which may explain the survival of children who have fallen into cold water and been submerged for long periods of time.

The diving reflex in mammals is mediated, in part, by receptors of the trigeminal nerve (cranial nerve V) in the face, nose and mouth, which respond to the temperature of the water. In diving mammals and humans as well, the stimulation of the trigeminal cold receptors in the nasal and pharyngeal passages results in powerful reflex apnea (cessation of breathing). In fact, approximately 30% of human drowning victims do not have water in their lungs because this powerful laryngeal reflex prevents breathing.

In this lab we will monitor heart rate, peripheral blood flow and blood pressure during a simulated dive. A number of parameters associated with underwater submersion will be varied in an attempt to identify the features of submersion that are important for the diving reflex.

Procedure: Equipment Set-up

1. Start the Labscribe software on your computer.
2. Pull down the **Settings menu**. First select Human Heart then select the **DivingReflex-LS2** settings file.
3. After a short time, LabScribe will appear on the computer screen as configured by the **DivingReflex-LS2** settings.
4. Plug the plethysmograph into Channel 3 on the iWorx unit. Wrap the plethysmograph around the volar surface of the middle finger on the subject's left hand. If the signal is noisy adjust the tension on the strap.
5. Plug the respiration monitor into Channel 4 on the iWorx unit. Wrap the belt around the subject so that the sensors are in the front and the belt sits just below the sternum even with the elbows.

Procedure: Heart Rate and Breathing at Rest

1. Remind the volunteer to sit quietly with their hands in their lap.
2. Click **Record**, and then click **AutoScale** for the Pulse and Heart Rate. If the pulse wave goes down, use the **Invert** function in the **down arrow** next to the word Pulse on the channel menu to orient the image in the correct direction.
3. When you have a suitable trace, type "Resting HR and BR" in the comment line to the right of the **Mark** button. Press the **Enter** key on the keyboard to attach the comment to the data. Record for at least one minute. However only record apneic data for a time span that is comfortable for the subject.
4. During the recording take the subjects blood pressure.
5. You will need three trials of this procedure.
6. Click **Stop** to halt recording.
7. Save the recording.

Procedure: Data Analysis

1. Click the **2-Cursor** icon so that two blue vertical lines appear over the recording window.
2. Drag the cursors left and right so that three complete breathing cycles are located between the two blue lines.
3. Click the **Analysis** icon to open the **Analysis** window.
4. Click the add function button and add **Mean** and **Max**.
5. Record the data for heart rate, breathing rate, systolic blood pressure, diastolic blood pressure and amplitude of peripheral pulse for each of the three trials in Table 1. Record an average of the three trials. Also calculate the MAP using the equation:

M.A.P. = diastolic pressure + 1/3 pulse pressure (systolic minus diastolic pressure)

Procedure: Effects of Anoxia

1. Using the same procedure for heart rate and breathing at rest, have the subject create an apneic condition by holding their breath. Make sure the subject knows not to exceed their ability is holding their breath because this is not an endurance test.
2. Again repeat this procedure in triplicate.
3. Analyze the data as described above record this in table 1 under the Apnea (no dive) conditions.
4. Now we will repeat the apneic conditions, however, now the subject will immerse their face in the room temperature bath while holding their breath (Apnea with dive). It is usually best if one group member is responsible for the iWorx readings and the other is responsible for the blood pressure recordings.
5. When the subject comes out of the water, it would be best to mark this with the iWorx unit, as this is the recovery phase. A blood pressure reading will also need to be taken during recovery.
6. Again, repeat this in triplicate.
7. Record your data in Table 1.

Table 1: Heart Rate and Breathing at Rest and Anoxia

	Control (resting)	Apnea (no dive)	Apnea (dive)	Recovery from Dive
Breathing Rate				
Trial 1				
Trail 2				
Trail 3				
Mean				
Heart Rate				
Trial 1				
Trail 2				
Trail 3				
Mean				
Systolic Blood Pressure				
Trial 1				
Trail 2				
Trail 3				
Mean				
Diastolic Blood Pressure				
Trial 1				
Trail 2				
Trail 3				
Mean				
Amplitude Peripheral Pulse				
Trial 1				
Trail 2				
Trail 3				
Mean				
MAP				

Procedure: Non-Apneic Conditions and the Effects of Facial Wetting

1. For these experiments, please refer to the experiments above for procedures and data analysis.
2. Perform a control (resting) reading again. Record data in Table 2.
3. Now use the snorkel and take a reading under non-apneic conditions without dive. Record this data in Table 2.
4. Use the snorkel and the facemask to take a reading under non-apneic conditions without dive. Record this date in Table 2.
5. Use the facemask only and have the subject hold their breath while diving. Record the data in Table 2 under Facemask Only (dive).
6. Use the snorkel only while diving. Record the data in Table 2 under Snorkel Only (dive). Only have the subject immerse their face for as long as they typically hold their breath.

7. Have the subject perform a dive with both the snorkel and the facemask. Only have the subject immerse their face for as long as they typically hold their breath. Record the data in Table 2.
8. Finally, have the subject perform the dive without both the snorkel and facemask. Record the data in table 2 under Dive.

Table 2: Non-Apneic Conditions and the Effects of Facial Wetting

	Control (resting)	Non-Apneic Snorkel (no dive)	Non-Apneic Snorkel & Facemask (no dive)	Facemask Only (dive)	Snorkel Only (dive)	Snorkel & Facemask (dive)	Dive
Breathing Rate							
Trial 1							
Trail 2							
Trail 3							
Mean							
Heart Rate							
Trial 1							
Trail 2							
Trail 3							
Mean							
Systolic Blood Pressure							
Trial 1							
Trail 2							
Trail 3							
Mean							
Diastolic Blood Pressure							
Trial 1							
Trail 2							
Trail 3							
Mean							
Amplitude Peripheral Pulse							
Trial 1							
Trail 2							
Trail 3							
Mean							
MAP							

Procedure: Effects of Water Temperature on Human Dive Response

1. Now repeat the experiment while the subject dives in room temperature water. Mark when the subject starts the dive. Take the blood pressure measurements after the subject has been submerged for at least 10 seconds.
2. Record the temperature of the water.
3. Repeat this experiment in room temperature water in triplicate.
4. Conduct the same experiments for cold water and warm water. Make the water cold using the ice provided. Warm water can be taken from the tap. If necessary allow the tap water to run awhile prior to use. Be sure to allow the subject plenty of recovery time between trials and experiments.
5. Record the temperature of the water for each experiment. Record the data in Table 3.

Actual Temperature of Room Temperature Water: _____

Actual Temperature of Cold Water: _____

Actual Temperature of Warm Water: _____

Table 3: Effects of Water Temperature on Human Dive Response

	Control (resting)	Dive Room Temperature	Dive Cold Water	Dive Warm Water
Breathing Rate				
Trial 1				
Trail 2				
Trail 3				
Mean				
Heart Rate				
Trial 1				
Trail 2				
Trail 3				
Mean				
Systolic Blood Pressure				
Trial 1				
Trail 2				
Trail 3				
Mean				
Diastolic Blood Pressure				
Trial 1				
Trail 2				
Trail 3				
Mean				
Amplitude Peripheral Pulse				
Trial 1				
Trail 2				
Trail 3				
Mean				
MAP				

Questions and Conclusions

1. What is the heart rate of the subject while they are holding their breath?

2. How does the subject's resting heart rate compare to their heart rate while they are holding their breath?

3. What happens to the subject's heart rate as their face is submerged in the room temperature water?

4. What happens to the subject's heart rate as their face is submerged in the colder water?

5. What caused the subject's heart rate to change when their face was submerged in cold water?

6. How would the mammalian diving reflex help a person who falls into cold water? Think in terms of the organs that need oxygen.