Name: ______________
Period: ______________
Date: ______________

Dolphin Physiology-The Retia Mirabilia

Introduction

Fluid physics is a branch of physical science that focuses on the movement of fluids. Scientists at NASA rely heavily on the study of fluid physics in order to make scientific advancements in space exploration and improve products designed for use on earth. An understanding of fluid physics helps geologists learn more about how magma moves underneath Earth's surface and how rivers carve out canyons here on the surface.

Living organisms are full of fluids, and biologists can use fluid physics to learn much more about these organisms. For example, an important fluid within the human body is blood. The human body contains an intricate series of blood vessels that are part of the circulatory system. The heart pumps blood into the lungs to be oxygenated. The oxygenated blood returns to the heart and is pumped into arteries, which carry the blood to tissues throughout the body. The oxygenated blood moves into capillaries, which have very thin walls. Oxygen, nutrients, and waste products are exchanged through the thin capillary walls. Once this has occurred, de-oxygenated blood moves into veins to be taken back to the heart. The blood will return to the lungs for re-oxygenation, and the process will repeat.

There are many things that can effect the movement of fluids through the body. The diameter of the blood vessels, the density of the liquid, and the rate of the heartbeat are just some of the factors that influence movement of fluids, and therefore our health. For example, it is essential that the brain receive a regular supply of oxygen from the blood. The carotid arteries carry blood through the neck to the brain. (If you've ever taken your pulse in your neck, you've felt the carotid arteries at work!) If this flow of blood is disrupted, a stroke can occur. This is possible if materials build up in the arteries and narrow their diameter, or if the heart rate drops below the number of beats per minute needed to sustain the body. (This minimum number of beats per minute is known as the resting heart rate. While it varies from person to person, it is usually between 60 and 80 beats per minute.) Conversely, if excess blood is sent to the brain, swelling and other problems can occur.

In contrast to humans, dolphin bodies are built to withstand large drops in heart rate. When a dolphin dives, its heart rate drops as low as 12 beats per minute. Dolphins store lots of oxygen in their blood, and the decreased heart rate helps the dolphin conserve oxygen while submerging. When resurfacing, a dolphin's heartbeat can skyrocket to 120 beats per minute. A dolphin is able to handle the quick change in blood pressure because of a special adaptation called the retia mirabilia (pronounced "*reesha muh-rabola*"). The retia mirabilia is a tissue found underneath the ribcage, between the blowhole and dorsal fin area. It consists of a dense mass of blood vessels that acts like a sponge. The arteries in a dolphin feed into the retia mirabilia, rather than going directly to the brain. The diverted blood flow saturates the vessels within the retia mirabilia, like a sponge, when a dolphin's heart rate is high. The retia mirabilia then controls the flow of blood to the brain, maintaining a consistent flow no matter how much blood is contained in its vessels. The retia mirabilia acts as a buffer, protecting against a surge of blood during high blood pressure, and against a lack of blood flow during reduced heart rates.

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Materials:
- Two beakers (300mL or larger)
- Funnel (250mL or larger)
- Sponge
- Water
- Stopwatch

Procedures:

Trial 1: Human A
1. Measure 250mL of water into one of the beakers.
2. Hold the funnel over the empty beaker.
3. Have one group member **quickly** pour all the water into the funnel. Simultaneously, have another group member use the stopwatch to time how long it takes all of the water to drain into the beaker below. (Hint: Start the stopwatch as soon as your classmate **starts** pouring the water, and stop the stopwatch as soon as all the water has drained out.)
4. Record the time in the space below.

Trial 2: Human B
1. Measure 250mL of water into one of the beakers.
2. Hold the funnel over the empty beaker.
3. Have one group member **slowly** pour all the water into the funnel. Simultaneously, have another group member use the stopwatch to time how long it takes all of the water to drain into the beaker below. (Hint: Start the stopwatch as soon as your classmate **starts** pouring the water, and stop the stopwatch as soon as all the water has drained out.)
4. Record the time in the space below.

Trial 3: Dolphin A
1. Measure 250mL of water into one of the beakers.
2. Saturate a sponge in water, and softly squeeze out some of the water. (It needs to be saturated, but not dripping wet!)
3. Fit the sponge into the funnel so that it covers the opening at the bottom of the funnel.
4. Hold the funnel over the empty beaker.
5. Have one group member **quickly** pour all the water into the funnel. Simultaneously, have another group member use the stopwatch to time how long it takes all of the water to drain into the beaker below. (Hint: Start the stopwatch as soon as your classmate **starts** pouring the water, and stop the stopwatch when there is no longer a **steady flow** of water draining out of the funnel.)
6. Record the time in the space below.

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Trial 4: Dolphin B

1. Measure 250mL of water into one of the beakers.
2. Saturate a sponge in water, and softly squeeze out some of the water. (It needs to be saturated, but not dripping wet!)
3. Fit the sponge into the funnel so that it covers the opening at the bottom of the funnel.
4. Hold the funnel over the empty beaker.
5. Have one group member **slowly** pour all the water into the funnel. Simultaneously, have another group member use the stopwatch to time how long it takes all of the water to drain into the beaker below. (Hint: Start the stopwatch as soon as your classmate **starts** pouring the water, and stop the stopwatch when there is no longer a **steady flow** of water draining out of the funnel.)
6. Record the time in the space below.

Results

Trial	Time (seconds)
1—Human A	
2—Human B	
3—Dolphin A	
4—Dolphin B	

Analysis

You will now need to calculate the rate of blood flow to the brain in each of the trials. I'm sure you're asking, "How am I supposed to do that? There was no blood or brain in the activity I just did! Well, you have to use a little imagination! For our purposes, the beaker sitting on the table represents a brain. The water being poured into the funnel represents blood being pumped from the heart to the brain. And the sponge? You'll have to determine what that represents. The rate of flow should be expressed in mL per second.

Trial	Rate of Blood Flow to the Brain (mL/sec)
1—Human A	
2—Human B	
3—Dolphin A	
4—Dolphin B	

Conclusions

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1. What was the difference in the rate of blood flow between Trials 1 and 2?

2. What was the difference in the rate of blood flow between Trials 3 and 4?

3. What anatomical structure does the sponge represent?

4. Why is the sponge only present in the trials representing dolphins?

5. Explain how the presence of the sponge resulted in a relatively constant flow of blood to the dolphin brain.

6. Which of the humans in your trials might be at risk of a stroke? Explain your answer.

7. Which of the humans in your trials might be at risk of brain swelling? Explain your answer.

8. Which dolphin would you assume is at the bottom of a dive? Explain your answer.

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9. Which dolphin would you assume is at the surface of the water? Explain your answer.

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