Respiration Lab

Pre-Lab Exercise **Name _____**

1. What is aerobic capacity and how is it defined?

2. What is the formula for the chemical reaction that produces ATP?

3. Briefly describe the test we will be using to determine our aerobic capacity.

4. Briefly describe the test we will be using to measure heart rate recovery after exercise.

5. How is homeostasis defined?

Respiration Lab
Work in groups of two or three

Metabolism comes from the Greek word for "change" and refers to all the chemical and energy transformations that occur in a cell. Food is transformed into energy in the mitochondria through aerobic respiration and the electron transport system. The overall chemical reaction for converting glucose into ATP is:

$$C_6H_{12}O_6 + 6O_2 + ADP \rightarrow 6CO_2 + 6H_2O + ATP$$

ATP is then transformed into mechanical energy to move our muscles and maintain our bodily functions. Since oxygen is required for making ATP, oxygen consumption is a reflection of metabolic activity. Energy expenditure, and thus metabolic rate, can be indirectly measured by measuring **oxygen uptake rate** (**VO_2**). VO_2 is the amount of oxygen that is actually consumed, not simply inhaled. VO_2 measured at rest will be lower than VO_2 measured during physical activity. It can be measured in Liters/minute, or in ml/kg/min.

VO_2 max is the amount of oxygen consumed when a person is working as hard as possible, or at maximal effort. Since VO_2 max is defined by the limits of one's oxygen transport system, it reflects a person's overall fitness level or **aerobic capacity**. Individuals who are more physically fit will be able to use oxygen more efficiently (have a higher VO_2 max), and can therefore produce more ATP and perform more work with less huffing and puffing. Factors that can affect VO_2 max include general respiratory and cardiovascular health, the amount of mitochondria in the muscle cells, and number of blood vessels in muscle tissue.

We will use a method called the McArdle-Katch Bench Stepping Test to <u>estimate</u> VO_2 max. It is a convenient, low budget method of fitness assessment that uses the proportional relationship between heart rate and oxygen consumption to estimate VO_2 max. The more oxygen you use, the higher your heart rate. We can measure heart rate while performing a **<u>sub-maximal</u>** amount of work, then extrapolate what our oxygen consumption **<u>would be</u>** if we were working maximally (VO_2 max).

This test is based on the assumption that a defined amount of work will require a given VO_2. A heart that is more fit will be able to provide the same amount of oxygen with fewer beats. In other words, if two people of the same age perform the same amount of work, the person who is more fit will have a lower heart rate than the person who is less fit. See Figure 1.

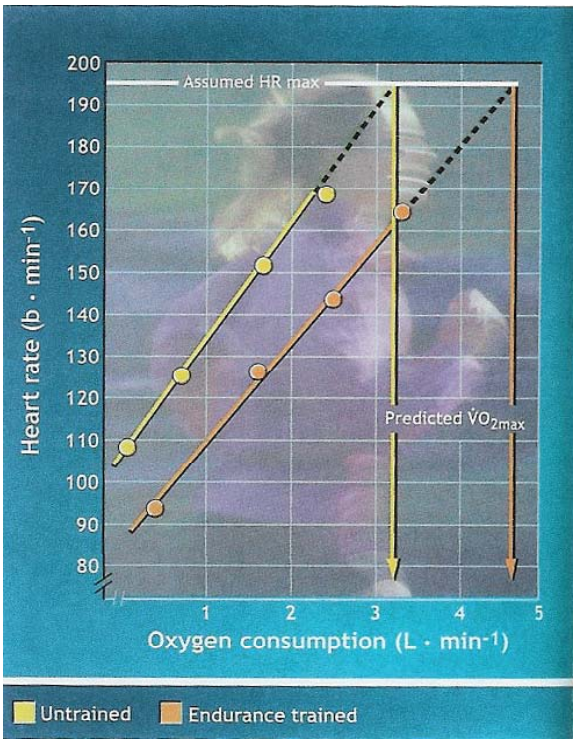

Figure 1. Relationship between heart rate and oxygen consumption

In addition to measuring VO_2 max, recovery time after exercise can also be used as an indicator of cardiovascular fitness. The oxygen debt incurred during exercise can be paid back more quickly if the ATP-producing apparatus in the cell is working more efficiently. Therefore, faster recovery time indicates better aerobic fitness. We will be using the 3-minute post-exercise heart rate as a second indicator of aerobic capacity. As activity level decreases and oxygen debt is repaid, heart rate decreases with the decreased need for oxygen.

Homeostasis is way in which the body responds to changes in the internal environment. As activity level increases, the body's need for oxygen increases and the body responds by increasing heart rate and respiratory rate. Homeostasis is often defined as "dynamic equilibrium", or an internal balance and is a characteristic all living organisms use to stay healthy and viable. Today we will be monitoring changes in heart rate in relation to physical activity to illustrate homeostasis.

Summary of Activities

1. Use the McArdle-Katch Bench Stepping Test to predict VO_2 max for each member of your group.
2. Correlate VO_2 max to each individual's aerobic fitness and the process of cellular respiration.
3. Measure post-exercise heart rate and correlate length of recovery time to aerobic fitness.
4. Apply post-exercise recovery of heart rate to the concept of homeostasis.
5. Determine an appropriate exercise regime for each of the various fitness levels.

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Predicting $V0_2$ max

The McArdle-Katch bench stepping test is used to predict VO_2 max by having the subject perform a defined amount of work and measuring their heart rate immediately after. The subject steps at a rate of 22 steps per minute (females) or 24 steps per minute (males) for 3 minutes. The bench height is 16.25 inches. Validity of the test is highly dependent on the accurate measurement of pulse rate. This test is considered to have an accuracy of $\pm$ 15% (W.D. McArdle et al. (1972) *Medicine and Science in Sports*, Vol. 4, p 182-186).

A. Before You Begin

1. Practice taking either your radial pulse in your wrist or your carotid pulse in your neck. If you use your radial pulse, place your index and middle fingers over the radial artery on the thumb side of your wrist just next to the tendons and press lightly.

   If you use your carotid pulse, place two fingers to the side of your trachea (windpipe) and below the angle of your lower jaw, just over the carotid artery.

   Whichever method you choose, do not press too hard or it will close off the artery and make it difficult to feel the pulse.

2. To calculate your resting heart rate (HR) in beats per minute (BPM), count the number of pulses in 10 seconds. Multiply this number by 6 to get beats per minute:

$$\mathbf{HR = \frac{heart\ beats}{10\ seconds} \times \frac{60\ seconds}{1\ minute}}$$

3. Record your results in Table 1.
4. Take your resting pulse two more times. How close were your three measurements? Calculate your average resting HR by adding the three numbers together and divide by 3.

B. McArdle-Katch Bench Stepping Test

1. Your lab partner will be your recorder and timekeeper. You partner will write down your data and signal you at each of the following time points:
   - 10 seconds before the 3-minute mark
   - 5 seconds post-exercise; take your pulse for 10 seconds
   - Every 1 minute for the next 3 minutes for 10 seconds each
2. Be sure you are wearing skid-resistance shoes, like athletic shoes or sneakers. Warm up a bit by gently stretching your leg muscles.
3. Set the metronome to 88 beats per minute for females or 96 beats per minute for males. You can turn off the sound of the metronome and use the flashing light to keep time if you prefer.
4. Brace the step stool against the wall to prevent it from slipping. Facing the back of the step stool, step up to the top step of the stool. Use a four-step cadence (up right, up left, down right, down left) for a period of **three minutes**, stepping in time with the metronome. The rate is 22 cycles per min for females and 24 cycles per min for males.
5. At the end of three minutes, remain standing and immediately find your pulse, using the same method you used to take your resting pulse. Start counting heartbeats when your timekeeper gives you the signal. Leave your fingers on your pulse so you don't have to search for your pulse for each recording.

Data Analysis

1. Plot your post-exercise heart rate recovery on page 6. Use only the numbers post-exercise. Create a scale for the X and Y axes.
2. Record all data into Table 2
3. Use the following formula to calculate your fitness rating:

Index of physical fitness = exercise duration (sec) X 100/sum of heart rate (bpm) at 1, 2, 3 minutes post exercise

4. Use table 3 to find your fitness rating.
5. Using the pulse rate measured at 0 seconds post exercise to estimate maximal oxygen consumption rate (in ml/kg/min) using the following equations.

Females:
VO_2 max = 65.81 – (0.1847 X HR)

Males:
VO_2 max = 111.33 – (0.42 X HR)

1. Use the standards provided in Table 4 for females and Table 5 for males to determine fitness level based on estimated VO_2 max.
2. Once fitness level has been determined, use Table 6 to an appropriate fitness regimen to establish or maintain good cardiovascular health.
3. Calculate your maximum heart rate (HRmax) in Table 2.
4. Calculate your target heart rate based on your level of fitness and your HRmax.

Respiration Lab
Data Sheets

Table 1. Heart Rate Data (in BPM)		
	Beats/10 sec	Heart Rate (BPM)
Resting Heart Rate #1		
Resting Heart Rate #2		
Resting Heart Rate #3		
Average Resting HR		
0 seconds post exercise		
1 minute		
2 minutes		
3 minutes		

Table 2. Calculations	
Index of Physical Fitness	
Estimated Fitness Level from Index of Physical Fitness	
VO_2 max (ml/kg/min)	
Estimated Fitness Level from VO_2 max	
Estimated Fitness Level from both tests	
Recommended % HRmax (from Table 6)	
HRmax (HRmax = 220 – age)	
Target Heart Rate for your fitness level	

Recovery of Heart Rate After Exercise

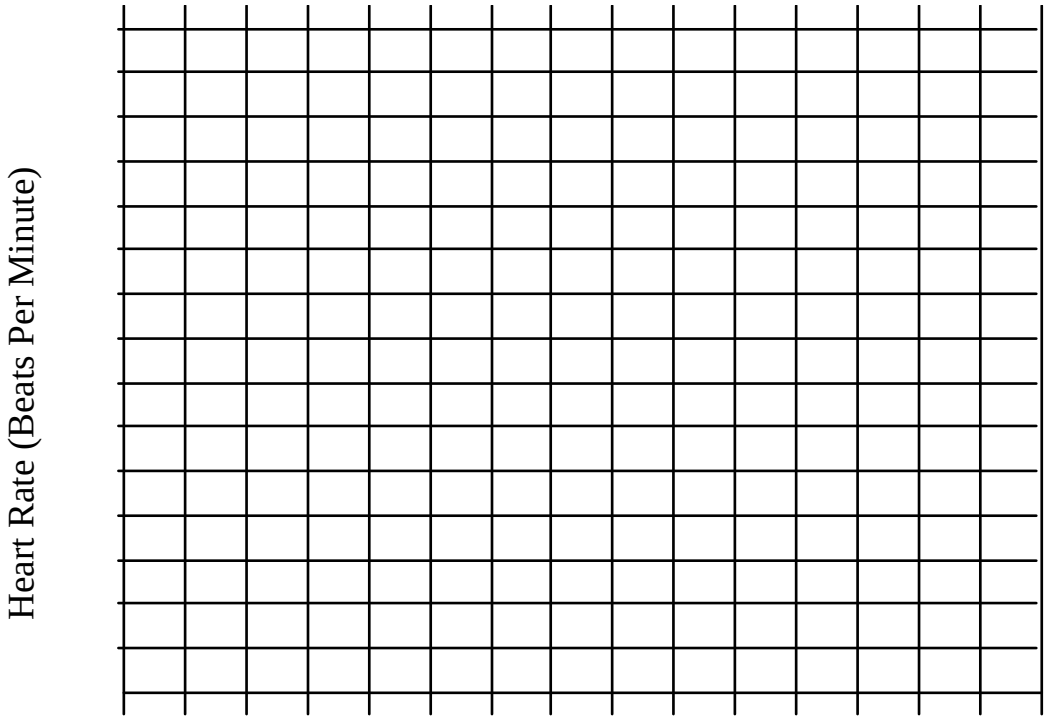

Table 3. Fitness Ratings for Heart Rate Recovery Post Excercise	
Index of Physical Fitness	Fitness Rating
> 90	High
80-90	Good
66-79	Average
55-65	Fair
<55	Low

Table 4. Maximal Oxygen Consumption Rates Standards (ml/kg/min) FEMALES					
Age (years)	Low	Fair	Average	Good	High
10–19	<30	30–37	38–46	47–56	>56
20–29	<26	26–32	33–42	42–52	>52
30–39	<24	24–29	30–38	39–48	>48
40–49	<21	21–25	26–35	36–44	>44
50–59	<19	19–23	24–33	34–41	>10
60–69	<18	18–21	22–30	31–38	>38
70–79	<16	16–19	20–27	28–35	>35

Table 5. Maximal Oxygen Consumption Rate Standards (ml/kg/min) MALES					
Age (years)	Low	Fair	Average	Good	High
10–19	<38	38 – 46	47 – 56	57 – 66	>66
20–29	<33	33 – 42	43 – 52	53 – 62	>62
30–39	<30	30 – 38	39 – 48	49 – 58	>58
40–49	<26	26 – 35	36 – 44	45 – 54	>54
50–59	<24	24 – 33	34 – 41	42 – 50	>50
60–69	<22	22 – 30	31 – 38	39 – 46	>46
70–79	<20	20 – 27	28 – 35	36 – 42	>42

Table 6. Exercise Prescription Guidelines Based on Fitness Level for Healthy Young Adults			
Fitness Classification Based on VO_2 max	Exercise Intensity	Exercise Duration	Exercise Frequency
Low to Fair Females: ≤ 29 ml/kg/min Males: ≤ 34 ml/kg/min	60-70% HRmax Perceived exertion: fairly light to somewhat hard Unaware of ventilation rate; Breathing and depth is comfortable; Capable of passing the "talk test"	20-30 min/session	3 days/wk
Average Females: 30-44 ml/kg/min Males: 35-49 ml/kg/min	70-80% HRmax Perceived exertion: somewhat hard to hard Aware of ventilation rate (i.e. increased breathing rate and depth)	30-45 min/session	4 days/wk
Good to High Females: ≥ 45 ml/kg/min Males: ≥50 ml/kg/min	80-90% HRmax Perceived exertion: hard to very hard Hyperventilatory response; respiratory distress (i.e. rapid breathing rate with deep or large breaths); Incapable of passing the "talk test"	45-60 min/session	5 days/wk

Go to the American College of Sports Medicine website at http://www.acsm.org/index.asp for more information on exercising and maintaining long-term cardiovascular health.

Respiration Lab
Report Questions

1. Hand in Data Sheets
2. What is VO_2 and how does it differ from VO_2 max? How does VO_2 max relate to cardiovascular fitness?
3. What physiological factors contribute to greater efficiency in cellular respiration?
4. What is the relationship between O_2 consumption and physical activity? How does homeostasis apply to your answer?
5. Why can heart rate be used to estimate energy expenditure?
6. The McArdle-Katch Bench Stepping Test is only about 85% accurate. What might be some reasons for this? How did your assessed fitness level compare to your prediction?
7. How is the heart rate recovery test different from the VO_2max test?
8. Why might it be appropriate to have different exercise regimens for individuals with differing fitness levels?
9. (2 pts) What might be some of the advantages **and** disadvantages to using **each** test to assess aerobic fitness?