This lesson defines exercise physiology and puts it into included in this exercise science. Also, some fundamental concepts are addressed in this lesson, such as the major types of the concepts introduced in this lesson will be covered in more detail in later lessons. Nothing in Lesson 1 is very "deep," physiology.

Assignments

1. Read Chapter 1 of the text.

3. Check the course Announcement Page for other possible assignments.

Contents of Lesson 1:

<table>
<thead>
<tr>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to Unit 1 - Lesson 1</td>
<td>1</td>
</tr>
<tr>
<td>Learning Objectives</td>
<td>2</td>
</tr>
<tr>
<td>Outline of Content</td>
<td>3</td>
</tr>
<tr>
<td>Definition and Description of Exercise Physiology: Normal and Abnormal Responses</td>
<td>5</td>
</tr>
<tr>
<td>Definition and Description of Exercise Physiology: Intensity Issues</td>
<td>6-11</td>
</tr>
<tr>
<td>Types of Exercise</td>
<td>12-13</td>
</tr>
<tr>
<td>Principles of Training</td>
<td>14-16</td>
</tr>
<tr>
<td>Review of Lesson</td>
<td>17</td>
</tr>
</tbody>
</table>
**Learning Objectives**

After completion of this lesson, you should be able to:

1. Describe what is meant by and included in the discipline of *exercise physiology*. Include in this description reference to anatomy, *normal vs. abnormal function*, and *pathology*.

2. State 10 specific examples of exercise, including five examples from competitive athletics and five examples that are not directly related to competitive athletics. For each of these examples, as well as other examples that may be presented, discuss what makes it "exercise" and the relative demands of strength, power and endurance. Include the concepts of *absolute intensity* and *relative intensity*.

3. Write definitions of *acute exercise* and *chronic exercise*, and illustrate each of these concepts with at least three examples.

4. Write a definition of *physiological mechanism*.

5. State four principles of training; for each, list two exercise examples that involve application of the principle and briefly discuss each example to clarify the application of the principle.

6. Write a definition of *overtraining* and briefly discuss a real or hypothetical example of overtraining.

**Outline of Content**

I. Definition and description of *exercise physiology*

   A. What is *physiology*?

   B. What is *exercise*?

II. Types of exercise

   A. Modes or devices

   B. Primary demand or stress

      1. Strength

      2. Power

      3. Endurance
III. Principles of training

A. Principle of Overload

B. Principle of Specificity

C. Principle of Reversibility

D. Principle of Optimization

- Definition and Description of Exercise Physiology

What is exercise physiology, or the physiology of exercise?

Let's start with the physiology part. Physiology and anatomy are two closely related branches of biology. Biology is the study of living organisms.

Anatomy is the study of the structure of living organisms.

Physiology is the study of the function of living organisms.

It is impossible to study either anatomy or physiology completely separately from the other. For example, we will study the function of the heart in this course. It simply is not possible to study cardiac function, dealing with variables such as left ventricular stroke volume, without at least a basic knowledge of the heart's structure. Nevertheless, physiology emphasizes function – function of tissues, organs, and organ systems, as well as function of the entire organism, the body.

- Definition and Description of Exercise Physiology: Normal and Abnormal Responses

Another aspect of physiology is that it deals with normal function, unaffected by disease. Pathology is the branch of biology that deals with study of structure and function related to diseases. Sometimes the term pathophysiology is used to specifically refer to the study of function related to disease. Just as one cannot study physiology without at least some reference to anatomy, one cannot study physiology without some reference to pathophysiology.
An important distinction must be made between the concepts of abnormal and diseased. Abnormal simply means "different from the average or typical." It does not necessarily mean there is underlying disease. To use a very simple example, if we know that heart rate increases from the resting value when we start to exercise, we then also know that if heart rate does not increase when a person exercises, this is an abnormal response. For a better example:

Suppose we have measured the heart rate of 1,000 people engaged in an aerobics class and found their heart rate values ranged between 120 and 170 beats per minute. Then, suppose we test a new individual engaged in the same exercise and found that his/her heart rate is 115 (or 180) beats per minute. We would correctly conclude that this person's response is abnormal compared to the group previously measured. In other words, the individual's heart rate response is different from the normal or usual responses measured in the group of 1,000 people. The response could be due to underlying disease (i.e., pathology), but NOT necessarily. It could just be an extremely unusual response.

To complicate matters a little more, just because a person has a certain disease doesn't mean he/she will have an abnormal response to exercise, or at least an abnormal response that is obvious. A common example of this is the person with narrowing of the coronary arteries (i.e., the blood vessels that supply the heart muscle with blood) who has an apparently normal response of heart rate, blood pressure, and other variables when exercising.

- Definition and Description of Exercise Physiology: Intensity Issues

In this course we will emphasize physiology (normal function apart from disease) rather than pathology. Nevertheless, we will also discuss abnormal function from time to time, including pathology. It is certainly important, and sometimes critical, that the physical education teacher and coach can distinguish between normal and abnormal responses of the body to exercise.

Now let's deal with the exercise part of exercise physiology.

Many times, P.E. teachers and coaches relate sports activities to exercise. Sure, running a 100-m sprint or a marathon is considered exercise. Playing in a football, basketball, or volleyball game is exercise. Working out with weights at the gym or at home is exercise. These are obvious examples, and important ones. Much of exercise physiology applies to such
However, exercise physiology is not merely a sports related science. Exercise physiology is also concerned with those activities that physical education teachers and coaches may not think about, but that are very important to the general population. Examples of other activities include: job-related physical activity (lifting loads, moving objects, walking and standing for eight hours, etc.), activities of daily living (doing laundry, mowing the lawn, cleaning house, cooking dinner, etc.), and rehabilitation of patients, such as following a stroke or heart attack. In all of these non-sport-related activities, exercise is involved. When we discuss exercise, we generally discuss it in terms of intensity and duration. You know, how hard was the work-out (intensity) and how long did it last (duration).

### Definition and Description of Exercise Physiology (cont.)

The intensity of the exercise may be very high such as lifting heavy loads for an eight-hour shift on the job, or it could be considered extremely low for an athlete such as, learning to walk again after a stroke or accident.

A word of caution here: The relative intensity of exercise depends on the person’s fitness related to the activity. Relative intensity is the intensity of exercise as a percentage of the person’s maximum capacity. In contrast, absolute intensity refers to the specific intensity regardless of the person’s maximum capacity. For example, If I were to ask each of you to curl a 50-pound barbell, the absolute intensity for everyone who lifts the weight is 50 pounds. But it may be a major challenge for some of you, especially if your maximum capacity to curl is 50 pounds. So, when we discuss relative intensities, we will discuss them in terms of percentage of maximum capacity.

An example of relative intensity:

Suppose we have two individuals lifting in a bench press competition. We know that individual 1 has a 1 RM of 100 pounds for the bench press and individual 2 has a 1 RM of 200 pounds for the bench press. ("RM" stands for "repetition maximum"; 1-RM refers to the load that can be lifted only one time.) We now ask each to bench press 75 pounds. The absolute intensity of the exercise is 75 pounds, but the relative intensity for individual 1 is 75% of his maximum capacity (75/100) and 38% (75/200) of individual 2’s maximum capacity. Therefore, in relative terms, individual 1 is exercising at a higher percentage of his maximum capacity than individual 2.
at a higher percentage of the maximum capacity compared to individual 2.

- Definition and Description of Exercise Physiology (cont.)

The duration of the exercise may be very long (e.g., working a double shift in a job involving manual labor) or very short (e.g., lifting bags of groceries out of the trunk and carrying them into the house; walking down the hall and back for the first time after coronary bypass surgery).

The exercise may be repeated day after day or even several times a day (e.g., letting the dog out of the house and taking it for a walk), or it may occur infrequently (e.g., changing a flat tire). In all cases the body must adjust to the demands placed on it by the exercise. If the body does not adjust appropriately, the person may be unable to do the exercise, may be unable to perform the task as needed, may be injured, or may even die!

In summary, the exercise physiologist must have a very broad view of what exercise is.

From the physiological perspective, it is useful to think about what the essential factor is that makes something exercise. I think it is contractions of skeletal muscles. Skeletal muscles exert force to (a) cause movement of the body or a body segment (e.g., lifting a weight, running, swinging a bat), (b) resist movement (e.g., lowering a weight, absorbing a hit in football, catching an object), or (c) prevent movement (e.g., holding the iron cross position on the rings in gymnastics, holding a football lineman's stance until the ball is snapped). It is the muscle contractions that do the activity we call exercise; without muscle contractions we don't do any exercise. Muscle contractions are fundamental. Then, a lot of other things have to happen in the body to support the muscular activity: adjustments of the heart's function, circulation of the blood, lung function, etc.
Exercise may be acute or chronic.

**Acute exercise** is a single bout of exercise: jogging for 20 minutes, lifting weights for an hour, playing a tennis match, changing a tire, mowing the lawn, etc.

**Chronic exercise** is exercise that is repeated over days, weeks, months and sometimes years. What we commonly refer to as training or conditioning programs are examples of chronic exercise.

**To summarize**, exercise physiology in the broadest sense is the study of how the body functions in response to any activity that involves skeletal muscle contractions.

Because the body is so complex, the responses of the body to acute and chronic exercise are also extremely complex. This is especially true if we would like to know the mechanisms that underlie the body’s responses.

**Mechanism** refers to the detailed explanation of a bodily response. For example, we will study the response of the body’s oxygen transport system to both acute and chronic exercise. We will see that with chronic endurance training the capacity of the oxygen transport system increases, that is, the body is able to use oxygen in energy metabolism at a higher maximal rate (often referred to as aerobic capacity, maximal aerobic power, or VO2max). Knowing that this response occurs is important, but the exercise physiologist would like to know what changes occur in the body to bring about this increase in oxygen transport capacity (i.e., the mechanism of this training effect). Scientists like to discover mechanisms simply to understand things better. But understanding mechanisms also often leads to better understanding of how things can be improved.

In this course we will study mechanisms to a certain extent. For example, we will study specific changes that occur in the heart’s function with months and years of endurance training that contribute to the increase in oxygen transport capacity. We will not be able to go into the really basic aspects of mechanisms, however, which are usually at the molecular level. In other words, ultimately changes in the organism (e.g., increased total-body VO2max) are caused by changes in
Increased total-body VO$_{2\text{max}}$ are caused by changes in organs, which in turn are caused by changes in tissues, which in turn are caused by changes in cells, which in turn are caused by changes in molecules! Really thorough understanding of exercise physiology requires study and understanding of cell and molecular biology. This degree of detail is beyond the scope of this class, however. We will deal almost exclusively with physiology of the entire organism (i.e., the body) and systems within the organism. To try to organize the many responses of the body to exercise, I think it is helpful to picture the body as a factory. The product this factory produces is exercise, and the skeletal muscles are the machines that make the product. Lots of things must happen in a coordinated way if the factory is to be effective.

- **Definition and Description of Exercise Physiology (cont.)**

For one thing, the machines themselves must be the right machines for the job, able to produce the desired product. That is, skeletal muscles must be able to generate appropriate force and have the necessary endurance.

The machines must be provided with power or energy. Metabolic adaptations must take place to transform energy from ingested food or stored depots, and changes take place in the heart, circulation and blood to transport the things needed by the muscle machines to keep going (e.g., glucose, fatty acids, oxygen).

A factory also has to be concerned with removal of waste products, so the environment stays appropriate for the machines to be effective. During exercise, for example, the body has to make a number of adjustments to handle the increased levels of waste products (e.g., carbon dioxide, lactic acid, and heat).

Finally, quality control is essential. If the machines are not closely monitored and adjusted as needed, the factory's product will be inferior. It is the responsibility primarily of the nervous and endocrine systems to control the skeletal muscle "machines" to be sure their output is precisely what is needed in the given exercise situation.

A big challenge in this course will be to see the big picture of the factory producing exercise of various types, intensities, durations, and frequencies, while at the same time seeing and understanding the individual components of the factory and how they work together.
- Types of Exercise

I want to overview several other very basic concepts and terms.

One of these has to do with categorizing the different types of exercise. There are at least two different ways the term "type of exercise" is used. One way is sometimes also referred to as the mode of exercise, and this means the specific exercise device (modality) used or task done. For example, I could design a training program to develop cardiorespiratory endurance fitness, and this program could be done on a treadmill, a bicycle ergometer, a rowing machine, or a stair-climber machine, or could use walking or jogging on a track. Each of these could be referred to as the type or mode of exercise. This is, of course, a very important part of prescribing exercise. Selecting the right mode for a given person in a given situation may be critical in terms of obtaining optimal benefits of training, in terms of safety and injury prevention, and in terms of what the person enjoys doing and what the person will actually do.

Very important in the study of exercise physiology is recognizing the type or category of exercise in terms of the primary demand or stress placed on the body. In this sense, there are three types of exercise: strength, power, and endurance.

**Strength** activities require high muscular force; they are necessarily of short duration, and power is not especially high.

We will study the specific meaning of power in exercise physiology in Lesson 2, but the important point related to analyzing the type of exercise is that **power** involves a combination of muscular force and speed. Activities involving the highest power involve rapid movements, but muscular forces are much less than maximal. High power activities are necessarily of short duration.

**Endurance** exercise requires continuation of the muscular activity for prolonged periods of time. Endurance is inversely related to muscular force and power. That is, the longer exercise must be continued, the lower the required muscular forces and especially power have to be.
- Types of Exercise (cont.)

Let me give a common example of each type of exercise.

Doing a **1-RM bench press** is a **strength exercise**. Obviously, high (maximal) muscular force is required. Even though force is high, the power is relatively low because the movement is relatively slow. And endurance is not a factor.

**Running 100 meters** in 9.79 sec (the world record as of May, 2000) is a **high power activity**. Muscular contractions are fast, but the muscular forces are not close to maximal. Again endurance is not a factor.

**Running a marathon** is clearly an **endurance activity**. The muscles involved in running do not generate high forces and they do not contract at particularly high speeds. But they must contract some 80 to 90 times per minute for at least 125 minutes (the world record in the marathon is 2:05:42), that is, at least 10,000 to 11,250 contractions during the race.

Note that this categorization of exercise activities emphasizes the **predominant** physiological demand or stress. In reality, most activities involve two or even all three of these demands, but in different proportions. Nevertheless, it is important to recognize the three basic types of physiological stress involved. These three types of exercise require very different adaptations by the body. Furthermore, the responses to training programs involving these three types of exercise are quite different. Therefore, it is very important to evaluate the involvement of strength, power, and endurance in an activity to be able to assess the requirement of each of these by the exerciser. (This is especially true in competitive athletics, in which optimal performance is the goal.) This in turn forms the basis for prescribing specific training to develop the performer. In this course, we will study physiological considerations related to these three categories of exercise.

- Principles of Training

Other concepts that I want to introduce early in the course relate to so-called "principles of training." Various exercise physiologists list different principles. I want to emphasize four, and the first two are the most fundamental: (a) Principle of Overload, (b) Principle of Specificity, (c) Principle of Reversibility, (d) Principle of Optimization.

The **Principle of Overload** is that the body or a body system does not improve its ability to function unless it is overloaded.
that is, subjected to stress that is greater than it is regularly subjected to.

The concept is pretty straightforward: the weight-lifter must lift heavier and heavier weights to continue to gain in strength; the distance runner must run more miles per week (within limits; see Principle of Optimization) to improve distance running performance. In practice, however, it is not always easy to quantify overload appropriately.

- Principles of Training (cont.)

The Principle of Specificity is that training adaptations are very specific. And they are specific in two ways.

First, the adaptations occur only in the specific tissues of the body that are stressed (overloaded) during training. An obvious example: Training by lifting weights doing arm curls will increase strength of the elbow flexor muscles, but will have no effect on strength of the calf muscles. A less obvious example: If a person trains with the same submaximal arm curls in every workout, certain muscle fibers in the elbow flexor muscles may be active while some remain inactive, because not all fibers are needed to lift the submaximal loads. In this case, the active fibers will gain some training benefit but the inactive ones will gain little or none.

The second aspect of the Principle of Specificity is that the training adaptation is specific to the demand of the training exercise. If high muscular force is demanded during the training, the trained muscles will adapt specifically by becoming stronger. If training involves repeated muscle contractions over a prolonged period of time, the trained muscles will adapt specifically to have improved endurance.

Proper application of the Principle of Specificity is essential for the optimal physiological development of an athlete.

- Principles of Training (cont.)

The Principle of Reversibility is actually a corollary or the opposite of the Principle of Overload, but it deserves some emphasis. The Principle of Reversibility is that gains in function with training reverse and are lost when the training stimulus is too low ("underload").
All functional gains from training are reversible – they can be lost. The term "detraining" is sometimes used to refer to a period or program during which function deteriorates. One example involves the athlete who must be relatively inactive due to injury. Another all-too-common example is the typical resident of the United States who has a very sedentary job and does not exercise during leisure time. This person is chronically detraining (a couch potato is detraining)!

The Principle of Optimization is that there is a single training program that produces optimal gains in function and performance. To a certain extent, this principle is theoretical, since no one can know for sure what the absolutely best training program is for a given athlete in a given set of circumstances. Nevertheless, athletes, coaches and exercise physiologists constantly search for this program.

Perhaps one of the most important practical aspects of this principle is that there can be too much training, so-called overtraining. In other words, the total training load can be so great that performance actually deteriorates. This is a topic of great interest to elite athletes and their coaches, and there is quite a bit of research being done to try to identify indicators of overtraining.

- Review of Lesson

You have come to the end of the online content of Unit 1 - Lesson 1. When you want to review the concepts in this lesson, go back to the Learning Objectives listed on Page 2 of this lesson. These should be a good study guide. If you can correctly do what the Objectives ask, you will have mastered the most important concepts in Lesson 1. Please realize, however, that those Objectives do not exhaustively cover all the information in Lesson 1.

If you are uncertain about any Objective, or if you want clarification or expansion of any point in Lesson 1, I urge you to start a threaded conference discussion in the "BARN" on WebBoard. Other students may have the same concerns, will probably benefit from the discussion, and may have the information you seek. And, of course, feel free to contact me (Dr. Eldridge) for assistance.

Be sure to check the Announcements Page to see whether there is a specific WebBoard or other assignment.