

## 15.3: Lactic Acid Fermentation

### Learning Outcomes

- Describe lactic acid fermentation.
- Describe how bacteria, including those we employ to make yogurt, make ATP in the absence of oxygen.
- Discuss how your muscles continue to work for you even when your respiratory and cardiovascular system can no longer keep up a continuous supply of oxygen.

Short spurts of sprinting are sustained by fermentation in muscle cells. This produces just enough ATP to allow these short bursts of increased activity.

### Lactic Acid Fermentation: Muscle Cells and Yogurt

For chicken or turkey dinners, do you prefer light meat or dark? Do you consider yourself a sprinter or a long distance runner? What is the biological difference between light meat and dark meat? Or between the two types of runners? Would you believe it has something to do with muscle color?

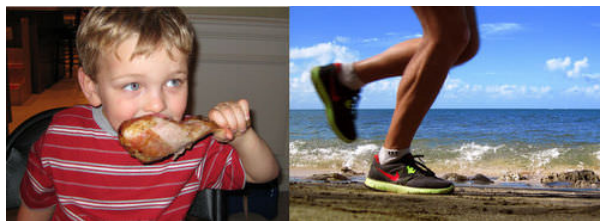


Figure 15.3.1: *Light meat or dark? Sprinting or endurance? Muscle cells know two ways of making ATP - aerobic and anaerobic respiration.*

### Are Drumsticks and Athletic Prowess Related?

Muscle color reflects its specialization for aerobic or anaerobic metabolism. Although humans are **obligate aerobes** (an organism which requires oxygen for cellular respiration), our muscle cells have not given up on ancient pathways which allow them to keep producing ATP quickly when oxygen runs low. The difference is more pronounced in chickens and grouse (see figure below), which stand around all day on their legs. For long periods of time, they carry out aerobic respiration in their "specialized-for-endurance" red muscles. If you are familiar with grouse, you know that these birds "flush" with great speed over short distances. Such "sprinting" flight depends on anaerobic respiration in the white cells of breast and wing muscle, allowing rapid production of ATP in low oxygen situations.



Figure 15.3.2: *Ruffed grouse use anaerobic respiration (lactic acid fermentation) in wing and breast muscles for quick bursts of speed to escape from predators.*

No human muscle is all red or all white, but chances are, if you excel at sprinting short distances or at a sport such as weight lifting, you have more white glycolytic fibers in your leg muscles, allowing anaerobic respiration. If you run marathons, you probably have more red oxidative fibers, performing aerobic respiration.

### Lactic Acid Fermentation

You may have not been aware that your muscle cells can ferment. **Fermentation** is the process of producing ATP in the absence of oxygen, through glycolysis alone. Recall that glycolysis breaks a glucose molecule into two pyruvate molecules, producing a net

gain of two ATP and two NADH molecules. **Lactic acid fermentation** is the type of anaerobic respiration carried out by yogurt bacteria (*Lactobacillus* and others) and by your own muscle cells when you work them hard and fast.

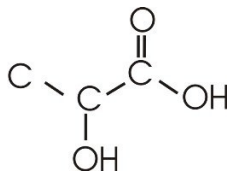
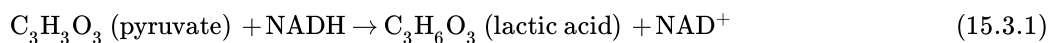


Figure 15.3.3: Lactic acid,  $\text{C}_3\text{H}_6\text{O}_3$ .

Lactic acid fermentation converts the 3-carbon pyruvate to the 3-carbon lactic acid ( $\text{C}_3\text{H}_6\text{O}_3$ ) (see figure below) and regenerates  $\text{NAD}^+$  in the process, allowing glycolysis to continue to make ATP in low-oxygen conditions. Since there is a limited supply of  $\text{NAD}^+$  available in any given cell, this electron acceptor must be regenerated to allow ATP production to continue. To achieve this, NADH donates its extra electrons to the pyruvate molecules, regenerating  $\text{NAD}^+$ . Lactic acid is formed by the reduction of pyruvate.



lactic acid fermentation converts pyruvate to lactic acid, and regenerates  $\text{NAD}^+$  from  $\text{NADH}$ .

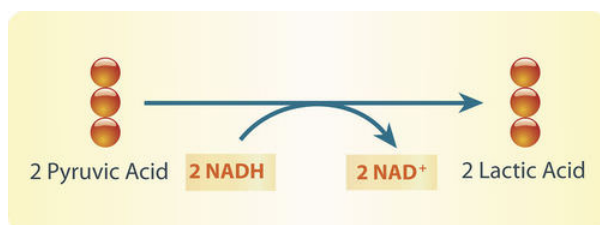


Figure 15.3.4: Lactic acid fermentation makes ATP in the absence of oxygen by converting glucose to lactic acid (through a pyruvate intermediate). Making lactic acid from pyruvate oxidizes NADH, regenerating  $\text{NAD}^+$  so that glycolysis can continue to make more ATP rapidly. Each circle represents a carbon atom.

For *Lactobacillus* bacteria, the acid resulting from fermentation kills bacterial competitors in buttermilk, yogurt, and some cottage cheese. The benefits extend to humans who enjoy these foods, as well (Figure 15.3.5).



Figure 15.3.5: *Lactobacillus* bacteria use the same type of anaerobic respiration as our muscle cells. Lactic acid reduces competition from other bacteria and flavors yogurt.

You may have notice this type of fermentation in your own muscles, because muscle fatigue and pain are associated with lactic acid. Lactic acid accumulates in your muscle cells as fermentation proceeds during times of strenuous exercise. During these times, your respiratory and cardiovascular systems cannot transport oxygen to your muscle cells, especially those in your legs, fast enough to maintain aerobic respiration. To allow the continuous production of some ATP, your muscle cells use lactic acid fermentation.

## Supplemental Resources

- Fermentation: <http://www.tempeh.info/fermentation/fermentation.php>
- Lactic Acid Fermentation: <http://www.tempeh.info/fermentation/...rmentation.php>

## Contributors and Attributions

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