LAB

8

Cell Respiration and Metabolic Rate

Food + **Oxygen** → **Carbon Dioxide** + **Water** + **ATP** + **Heat**

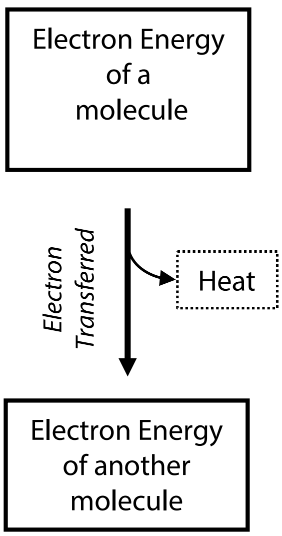
Metabolism is derived from a Greek word meaning "change" – food is changed into life. It includes all of the biochemical reactions in the body that are responsible for growth, activity, reproduction, and everything else discussed in this course. The specific extraction of energy from food is usually called ***cell respiration***, and the organic building reactions (making proteins, fats, nucleotides, and others) are called ***synthesis***. Living organisms extract electron energy from the chemical bonds in organic molecules (food), and they convert that energy into a more useful form of energy (called ATP) to run cell activities. This cell process uses oxygen and produces carbon dioxide. This week's lab will investigate factors affecting metabolism and metabolic rate. Exercise #1 is a tutorial on Cell Respiration intended to help you in lecture class. It may be skipped as part of this lab.

Exercise #1	**Tutorial on Cell Respiration** (optional for this week)
Exercise #2	**What is Metabolism?**
Exercise #3	**Metabolic Rate and Environmental Temperature**
Exercise #4	**Comparison of Endotherm and Ectotherm**
Exercise #5	**Food Demand for Humans**
Exercise #6	**Dietary Supplements for Increasing Metabolism**

Exercise #1
Tutorial on Cell Respiration (Optional)

Chemical Breakdown of Food

The part of metabolism that is involved with the chemical breakdown of food is called ***cell respiration***. You can understand much about cell respiration by using basic rules of chemical reactions.



Rule: You can best understand what is happening during the metabolic process by following the electrons.

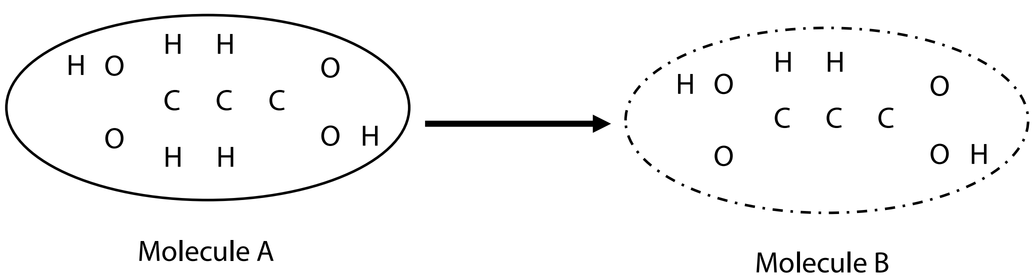
Rule: Electrons have energy.

Rule: Sometimes electrons can be moved from one molecule to another. When that happens the molecule gaining the electron is gaining energy. The other molecule is losing that energy.

Rule: Whenever hydrogen atoms are shown to be added to or removed from a molecule in a chemical reaction, assume that the same number of electrons are being moved (one hydrogen added = one electron added).

Rule: The Second Law of Thermodynamics applies to all situations where the electron energy of one molecule is transformed into the electron energy of another molecule. Some heat is always released. This is the same heat released during your metabolism.

Example of a "break down" reaction during metabolism.



? Question

1. In the reaction shown above, is Molecule **A** gaining or losing electrons?

2. Is Molecule **B** gaining or losing energy?

3. Which has more electron energy?

   $C_6H_{12}O_6$ or $6CO_2$

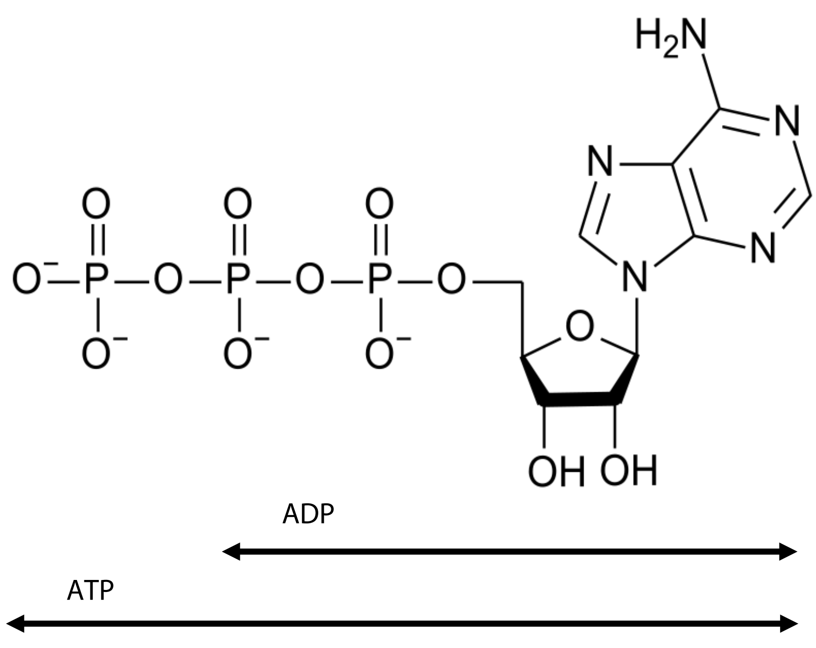
4. How many electrons are removed from sugar ($C_6H_{12}O_6$) during cell respiration when it is broken into $6CO_2$ and water?

The energy of one electron from food can be transformed into the electron energy of 3 ATP molecules.

5. Cells need a special molecule called ATP to do the work of life. Assume that the energy of one electron from food ($C_6H_{12}O_6$) can be transformed into the energy of 3 ATP molecules. How many ATP molecules are generated by the breakdown of one sugar molecule during cell respiration? Refer to your answer for question #4.

ATP

ATP (adenosine triphosphate) is a special high-energy molecule in the cell. This molecule can also exist in a low-energy form called ***ADP*** (adenosine diphosphate). ATP has more high-energy electrons than ADP. That extra electron energy comes from food molecules. ATP is like a "cell battery" that is charged up by food.



Energy Exchange System

Figure 8.1. The chemical structure of ATP has one more phosphate group than ADP. That phosphate group has high energy electrons.

ATP delivers high-energy electrons to other energy-requiring processes in the cell. The two processes (ADP "charged" to ATP) and (ATP "discharged" to ADP) create an energy exchange system in the cell.

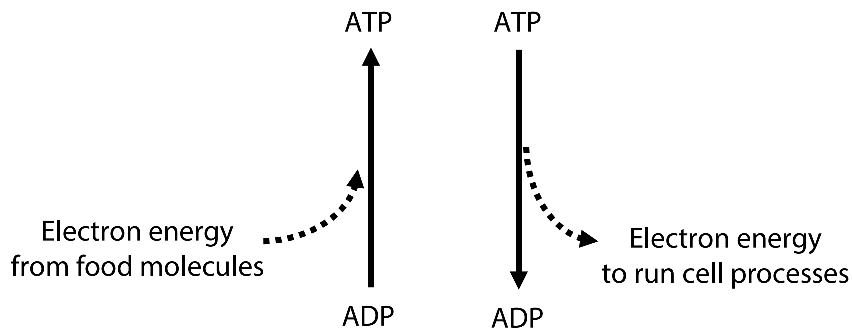


Figure 8.2. The energy exchange system of metabolism.

Cell Respiration – Anaerobic and Aerobic

Chemists tell us that some chemical reactions can happen without oxygen. Can any part of the breakdown of food proceed without oxygen? The answer is yes. Respiration can occur without oxygen, and there were primitive cells living only by this process before photosynthesis or aerobic respiration evolved on Earth.

ATP is like a "cell battery".

Respiration without oxygen present is called ***anaerobic*** (without air). Respiration with oxygen is called ***aerobic***. Aerobic respiration occurs inside a specialized organelle called the ***mitochondrion***, whereas anaerobic processes (also called *fermentation*) are associated with other membranes in the cytoplasm. The sugar molecule is only partially broken down during anaerobic respiration. Have all high-energy electrons been removed from the sugar molecule below?

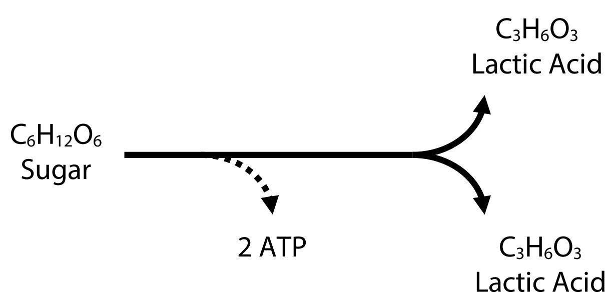


Figure 8.3. Anaerobic Respiration. A sugar molecule is split into two lactic acid molecules, and only 2 ATP of energy is captured.

You shift to anaerobic respiration when the muscles run out of oxygen.

The energy of two ATP molecules is captured by the cell when sugar is "split" into the two lactic acid molecules. These two ATP molecules are the only energy captured from the food molecule during anaerobic respiration. High-energy electrons remain in the lactic acid, and they have not been captured by the cell. Previously you calculated that 36 ATP are generated during aerobic respiration. Anaerobic respiration is very inefficient compared to aerobic respiration.

At some point during a hard run you will shift into anaerobic respiration and only make 2 ATP for each sugar molecule being used as fuel. You must then radically speed up anaerobic respiration so that the needed ATP continues for muscle contraction. You are now burning sugar 16X faster and producing lactic acid 16X faster than when the aerobic process is providing your ATP. Eventually you must stop and replenish the sugar and reprocess the lactic acid. By the way, lactic acid buildup is partially responsible for the pain you feel in the muscle during the next day.

In humans, anaerobic respiration happens for short periods of time and only in the skeletal muscles. During strenuous exercise this maintains metabolism when oxygen is temporarily depleted. Other organs of your body are incapable of anaerobic respiration, and their cells are damaged or die when oxygen is used up.

Aerobic Respiration

Aerobic respiration is the efficient process of extracting electron energy from the chemical bonds in organic molecules (food) and converting that energy into the most useful form of energy (called ATP) to run cell activities. This cell process uses oxygen and produces carbon dioxide. The complete equation is:

$$\text{Food} + \text{Oxygen} \longrightarrow \text{Carbon Dioxide} + \text{Water} + \text{ATP} + \text{Heat}$$

Aerobic respiration occurs inside the ***mitochondria***, which are cellular organelles in both plant and animal cells. The mitochondria have a remarkable structure that is somewhat like a factory. The high-energy electrons are stripped off the food molecule in the fluid matrix, and then the energy of those electrons is used to generate ATP energy along the cristae membranes.

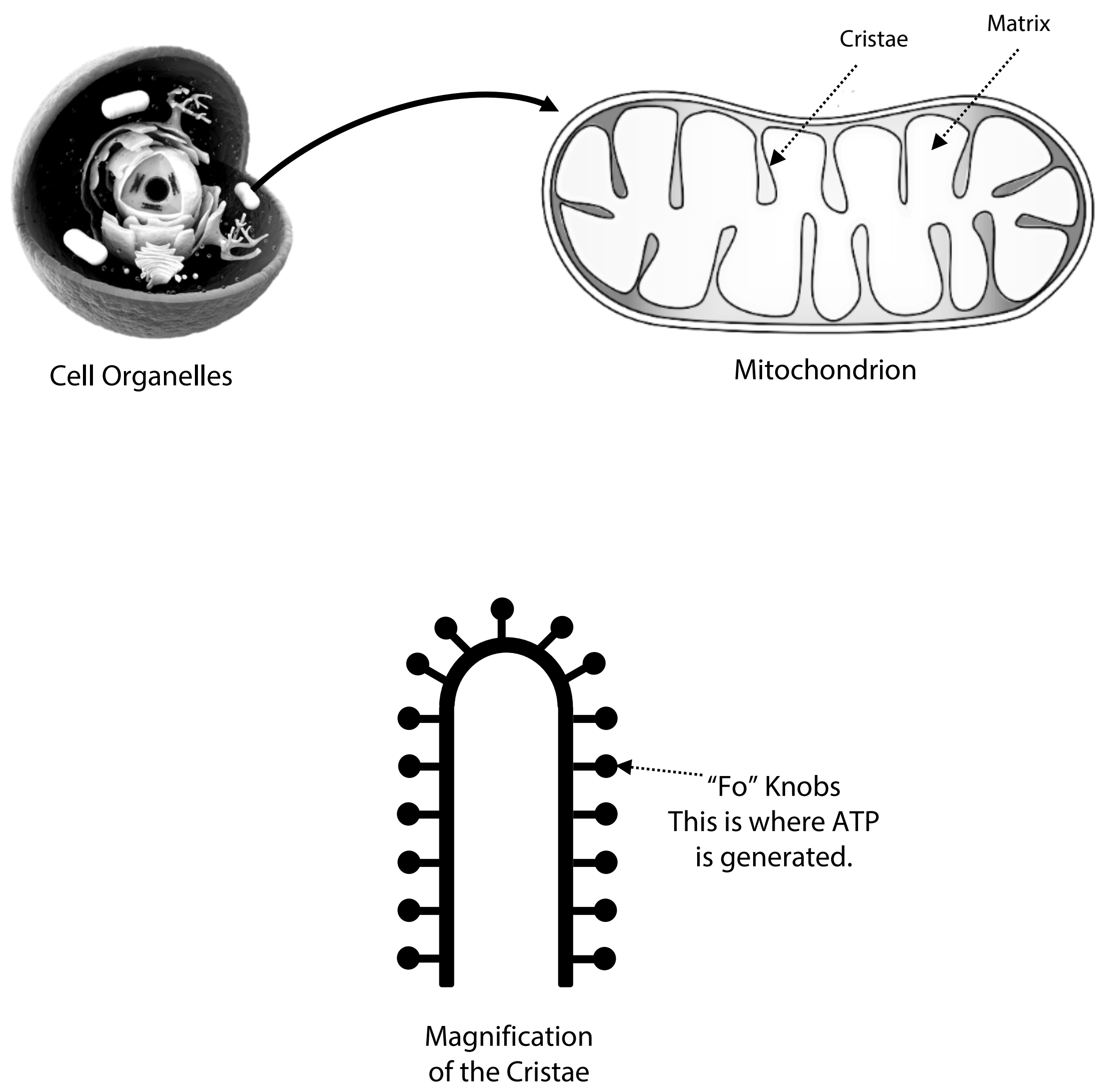


Figure 8.4. Structure of the mitochondria. This is the location of aerobic respiration.

? Question

1. Which is the high energy form – ADP or ATP?

2. Define aerobic respiration.

3. Where in our body does anaerobic respiration occur?

4. What substance builds up when we shift to anaerobic respiration?

5. Some of the cells of your body have many mitochondria and other cells have few mitochondria. Why would there be differences?

6. Complete the following table comparing aerobic and anaerobic respiration.

Table 8.1. Comparison of Aerobic and Anaerobic Respiration.

Comparison	Aerobic	Anaerobic
Is oxygen necessary?		
Which came first on the planet?		
What are the end products?		
How much ATP energy is generated?		
Where in the cell does it happen?		

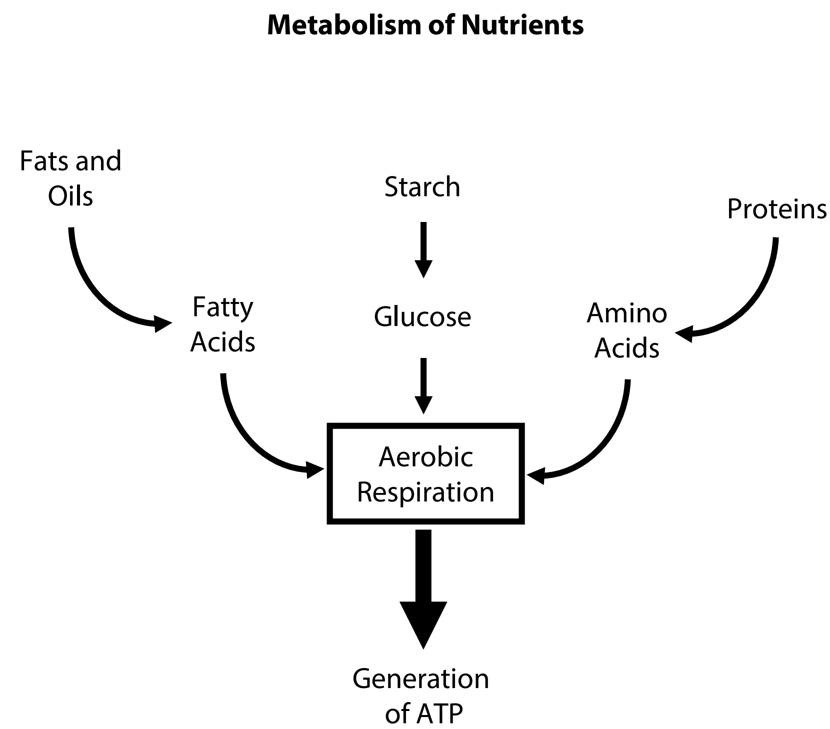


Figure 8.5. Carbohydrates, Fats, and Protein are fed into aerobic respiration. They generate ATP as the universal energy supply for cell processes.

Sugar is not the only source of energy.

Sugar is not the only type of food molecule that can be metabolized during cell respiration. Fats, proteins, and starch are other energy sources for the generation of ATP. The amount of ATP produced from these nutrients depends on the size of the molecule and the number of high-energy electrons that can be stripped off. Starches are easy to metabolize because they consist of glucose sugar molecules hooked together. Starches are quickly digested into monosaccharides in the intestine. Proteins also are broken into amino acids in the intestine and then modified into fuel by body cells. During the process of protein metabolism, nitrogen atoms are broken off the amino acid molecule. Ammonia is produced from that nitrogen, and the ammonia is then converted into urea and dumped into the urine. The part of the amino acid remaining after nitrogen removal can be used as a fuel by aerobic respiration. Amino acids generate about the same amount of ATP energy as does an equal weight of sugar.

Fat molecules have many more high-energy electrons than an equal weight of either sugar or protein. Protein and sugar provide about 4 Calories of energy per gram. Fat provides about 9 Calories of energy per gram. You can see why it's easy for those high-energy electrons to pile up!

? Question

1. What factor determines the amount of energy that can be extracted from a nutrient molecule?

2. Which nutrient provides the most ATP energy per molecule metabolized?

3. Urea is one of the substances that gives urine its characteristic smell. Urea in the urine means that you have been metabolizing which nutrient?

Exercise #2
What is Metabolism?

Historical Discovery Process

The earliest experiments on metabolism were performed about 300 years ago and involved both plants and animals. Very little was understood about chemistry, so most explanations depended on unseen forces and substances.

Description of Experiment	Results
Mouse in a sealed jar	Mouse dies in an hour or so.
Mouse in a sealed jar with a large plant in the light	Mouse lives just fine.
Mouse in a sealed jar with a large plant in the dark	Mouse dies in an hour or so.

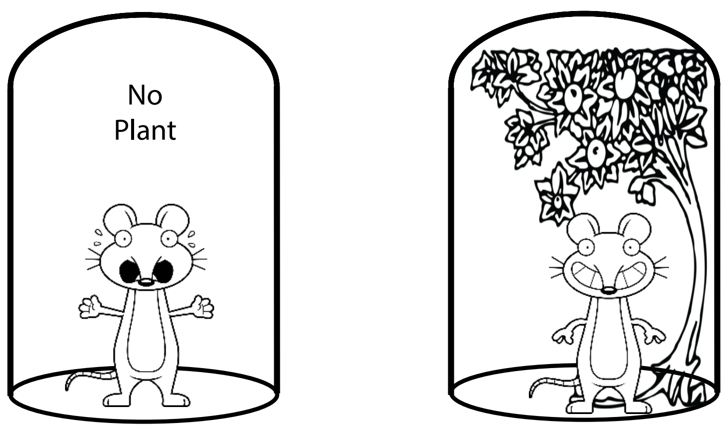


Figure 8.6. Early experiments on metabolism.

"I'm outta' here guys!"

These early experiments revealed several facts. There is something in the air that animals need to live. Somehow plants "regenerated" the air that animals need, and light was necessary. Later experiments measured the changes in the weight of substances during metabolism, and it did not take long for the gaps to be filled in.

Mouse in a sealed jar with enough air but no food.	$\longrightarrow$	**Experimental Results:** Mouse loses weight. Mouse produces water. Air gets heavier.

The chemists soon learned that:

- Mouse Tissue can be represented by the formula for sugar - $C_6H_{12}O_6$.
- Light Air is oxygen - O_2.
- Water is H_2O.
- Heavy Air is carbon dioxide – CO_2.

The general equation for the metabolic process became:

$$\text{Mouse Tissue} + \text{Light Air} \longrightarrow \text{Water} + \text{Heavy Air}$$

? Question

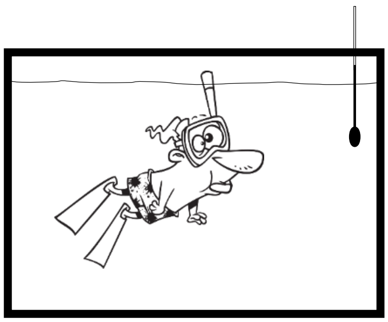
1. Write the molecular formulas below the words in the general equation (above) for metabolism.

2. When radioactive isotopes of oxygen atoms are put into O_2 molecules and the mouse is allowed to metabolize in a chamber with that “labeled” oxygen, only the H_2O produced by the mouse is radioactive. Based on that evidence, draw dotted lines to show where each atom on the left side of the equation goes to on the right side of the equation.

3. Where does the CO_2 that you breathe out specifically come from during metabolism? Draw dotted lines to show this.

4. Where does the O_2 that you breathe in specifically go to during metabolism? Draw dotted line to show this.

Measuring Metabolic Rate



This is a very accurate method, but it is expensive and difficult.

Energy output is the term used to represent all of the energy required to maintain the metabolic processes and activities of an organism. The most accurate and direct way of determining the amount of energy used by the body during an activity is to measure the ***amount of heat given off***. Physics tells us that heat is released whenever energy is transformed from one form into another (such as nutrient energy into physical work). A technical problem with using this method of analysis is that the person must be inside an insulated container surrounded by a known quantity of water. The temperature of the water increases as heat is released by the person. Although this procedure is very accurate, it is also expensive and difficult.

The usual method of measuring energy output is the ***oxygen consumption technique***. If the oxygen requirement of a resting person is known, then that value can be compared to the increased amount of oxygen used during a particular physical activity. This approach is easier and less expensive than the heat method. Most general studies of energy expenditure are based on oxygen consumption.

Figure 8.7. The oxygen consumption method for measuring energy output is much easier to do.

Factors Affecting Metabolic Rate

It is possible to estimate how much energy you expend during the day using tables and calculations. The basic calculations involve two parameters.

Energy Output = BMR + Daily Activity

- **Basal Metabolic Rate (BMR).** This is the fuel burning rate (O_2 consumption) required to maintain resting body needs. It is influenced by sex, age, and other factors.

- **Amount of Daily Activity.** This is all of the work and movement you do during the day beyond BMR.

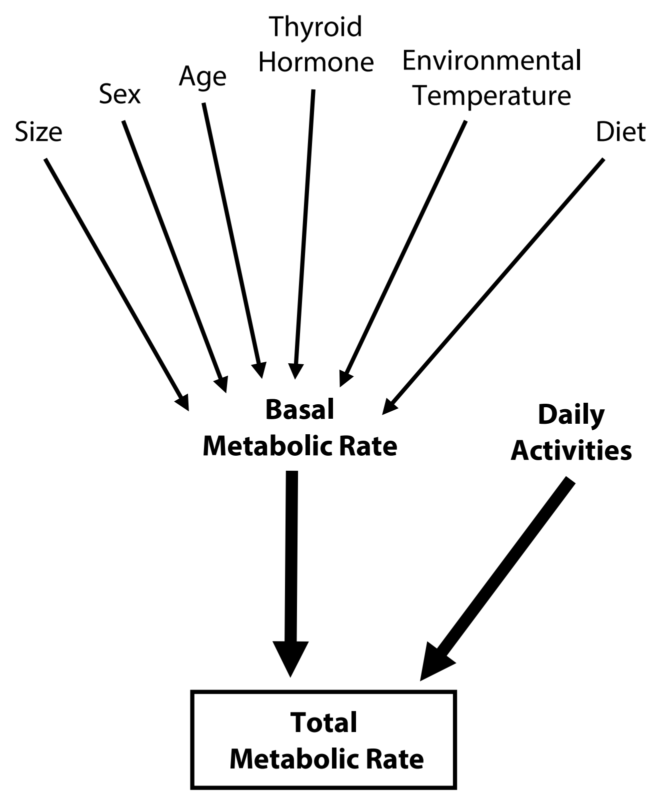


Figure 8.8. Factors that influence the metabolic rate. Basal Metabolic Rate plus Daily Activities equals Total Metabolic Rate.

The total metabolic rate is the product of BMR plus all daily activities. Physical activity can increase metabolism to 10X BMR. This is the dominant influence on metabolic rate. We will examine the details of metabolic rate during physical activities in another lab.

Important factors affecting BMR are shown in Figure 8.3. The effect of size on BMR is best described by surface area and not by weight. If a 100 lb person has a BMR of X, then the BMR of a 200 lb person won't be 2X. It will be X plus about 30% more. Smaller people metabolize faster per pound even though larger people eat more food. This can be somewhat frustrating for one of your larger clients to accept. They may naturally think that they need much more food than a smaller person. They don't.

Sex and age also impact BMR. The female is usually 5-10% lower than a same-size male, and BMR drops about 0.2% each year after the age of 2 or 3. Another determinant of BMR is the amount of thyroid hormone. This hormone directly influences the speed of carbohydrate and fat metabolism. Thyroid hormone can increase BMR to 2X normal, and it is part of the stress reaction. Another part of the stress reaction is the sympathetic nervous system which can increase BMR almost as much as thyroid hormone, but its effects last only an hour or two. Diet and environmental temperature have smaller effects on metabolic rate. The BMR can be increased 10-30% after eating. The stronger effect comes after meals that are higher in protein.

Finally, the influence of environmental temperature is significant, and we will study it next. Our metabolic rate increases in a cold environment in order to produce more heat for maintaining a normal constant body temperature.

? Question

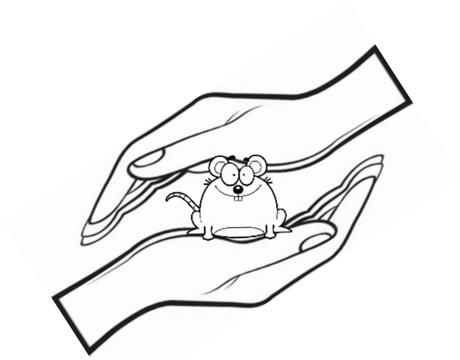
1. Why would measuring the amount of heat given off by an organism be useful for estimating metabolic rate?

2. Why is the oxygen consumption method the usual way to estimate the metabolic rate?

3. Does a 200 lb person metabolize twice as much as a 100 lb person?

Exercise #3
Metabolic Rate and Environmental Temperature

Metabolic Rate of a Mouse

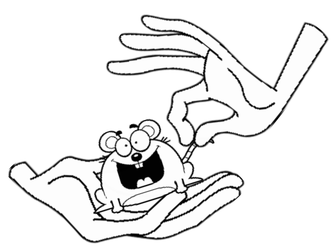


These are professional mice, and we treat them well.

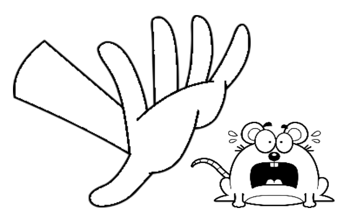
Mice are ***endotherms***. That is, they get most of their heat from inside their own body (endo means inside). Cellular respiration generates the heat that keeps these animals warm. During this Exercise you will monitor the rate of cell respiration (also called metabolic rate) in a mouse. Then you will investigate the influence of environmental temperature on metabolic rate by comparing the mouse in a cold environment with what you observe at room temperature.

How to Handle Mice

- Mice should be picked up by their tail and immediately rested on your hand, and then marched into the Metabolic Cage.
- Do not grab them. Grabbing scares the hell out of them, and they may bite you or pee on you because of that fear.
- Also, don't play with the mice (on table tops, etc.) because there is a possibility of them getting loose on the floor. These are professional mice. They work several years for us, and we treat them very well. So, please be careful.



Right



Wrong

Experimental Design – Room Temperature

The basic question is: ***What effect does environmental temperature have on the metabolic rate of an endotherm (mouse)?*** Do this experiment at two temperatures: Room Temperature and Packed in Ice.

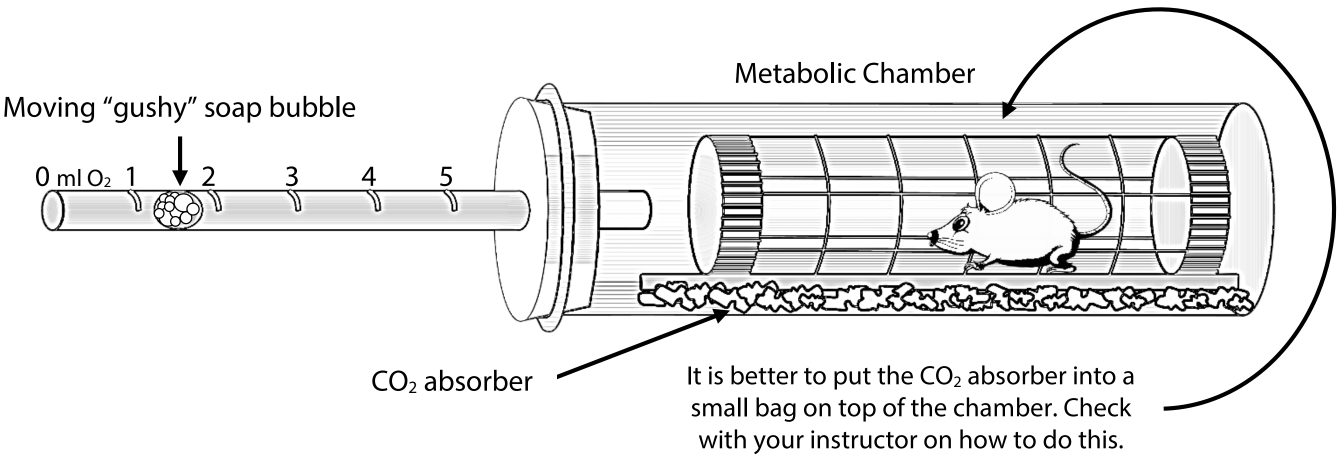


Figure 8.9. Design of the metabolic chamber. The soap bubble will move as oxygen is consumed by cell respiration in the mouse.

Procedure

- Weigh the wire cage part of the chamber: _______ grams.
- Go get your mouse, and put it into the wire cage. Then weigh the cage with the mouse in it.
  Weight of the mouse = _____ grams.
- If your class is using small bags of CO_2 absorber instead of loose material, then place one bag on top of the mouse cage so the mouse can't pee on it. Otherwise, put one tablespoon of CO_2 absorber (soda lime) into the trough at the bottom of the Metabolic Chamber.
- Wet the inside of the glass tube with soapy water. This will help prevent the "gushy" soap bubble from "popping" during the experiment.
- Put the caged mouse into the chamber and seal the cork tightly. Don't worry! The mouse won't suffocate. Leave the chamber alone for 10 minutes (sealed up with cork on and no soap bubble). This will equalize the temperatures inside and outside of the chamber.
- Use your finger to make a "gushy" soap bubble on the open end of the glass tube. Measure the time it takes (in seconds) for the bubble to move between the marks on the tube. This bubble movement indicates that 5 ml of O_2 have been consumed by the mouse.
- Perform three trials, and record the results.

Time for Mouse to Consume 5 ml of Oxygen (in seconds)	
Trial 1	
Trial 2	
Trial 3	

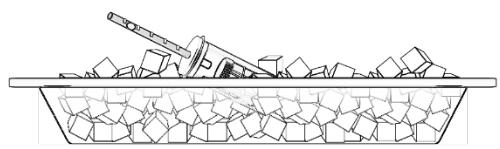
? Question

1. During cell respiration a mouse will consume O_2, and CO_2 will be produced in its place. If no CO_2 absorber had been used in your experiment, would you have seen a change in air volume?

2. If you use a CO_2 absorbing substance in the Metabolic Chamber, then what happens to the CO_2 that is produced during cell respiration?

3. Now, with the absorbing substance in the chamber, what happens to the air volume during your experiment as the O_2 is consumed during cell respiration?

Experimental Design - Packed In Ice



Procedure

- If ice is packed around a Metabolic Chamber like the type we are using, the temperature inside will stabilize at 5°C. This cold temperature will not harm the mouse as long as it is removed before 45 minutes. Our experiment will take less than 20 minutes.
- Let the "Packed in Ice" chamber equalize temperature for 10 minutes before applying the "gushy" soap bubble. (The chamber should be sealed during this 10 minute period.)
- After the 10 minutes of temperature equilibrium, apply a "gushy" soap bubble and perform three separate measurements of metabolic rate. Record the results.

Time for Mouse to Consume 5 ml of Oxygen	
Trial 1	
Trial 2	
Trial 3	

- Disassemble the chamber and carefully return your mouse to its home. Return the CO_2 absorber to its storage container, and dump feces into the special waste jar. Don't wash the apparatus unless you are told to do so. The chamber must be dry for the next lab class. Wash your hands!

Calculations of Metabolic Rate

You must convert the mouse's O_2 consumption to an hourly metabolic rate. Calculations 1 and 2 will make that conversion. This is accomplished by dividing the bubble time (in seconds) into 3,600 (the number of seconds in one hour). The resulting number is to be multiplied by 5 (5 ml of O_2 used in each trial).

Calculation 1

Calculate the average time of the three trials at room temperature.

5 ml O_2 consumed in ____ seconds. (Room Temperature - $\approx 20^0$C)

Calculate the average time of the three trials packed in ice.

5 ml O_2 consumed in ____ seconds. (Packed in ice - $\approx 5^0$C)

Calculation 2

Based on Calculation 1, how much O_2 would your mouse consume in one hour? (There are 3600 seconds in one hour.)

$$\frac{3600}{\text{Calculation 1}} \times 5 = \_\_\_\_\_ \text{ ml } O_2 \text{ consumed in one hour}$$

O_2 consumed in one hour at room temperature = _____ ml.

O_2 consumed in one hour packed in ice = _____ ml.

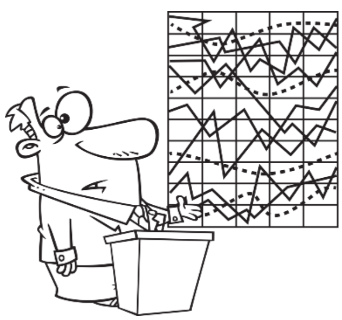
Calculation 3

In order for the metabolic rate of a mouse to be compared with a bigger or smaller animal, we must correct the calculations considering the mouse's weight. Use the following equation.

$$\frac{\text{Calculation 2}}{\text{Weight of Mouse}} = \underline{\qquad}\ \text{ml } O_2 \text{ per hour per gram of weight}$$

Metabolic Rate of your mouse at room temperature (20^0C) = ______ ml O_2 per hour per gram of weight

Metabolic Rate of your mouse packed in ice (5^0C) = ______ ml O_2 per hour per gram of weight



Time for graphing.

- Put a dot on the graph in Figure 8.10 for each of the metabolic rate values in your experiment.
- Draw a line between those two dots.
- Write the word "endotherm" on that line.
- Check with other lab groups to see how your calculations compare with theirs.

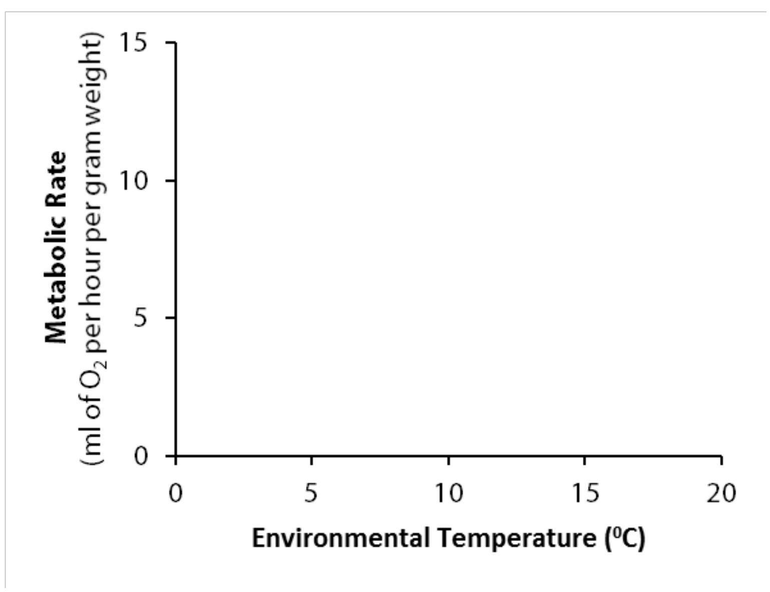


Figure 8.10. Effects of environmental temperature on the metabolic rate of an endotherm (mouse).

Exercise #4
Comparison of Endotherm and Ectotherm

A frog in the cold is cold!

An ***ectotherm*** (ecto means outside) gets its heat from the environment. The body temperature of an ectotherm is warm when the environment is warm, and the body is cooler when the environment is cold. The following results are taken from experiments that measured the metabolic rate of a frog (ectotherm) of about the same size as your mouse.

Table 8.2. Measurement of the Metabolic Rate of a Frog at Different Environmental Temperatures.

	Metabolic Rate Packed in Ice (5^0C)	**Metabolic Rate** Room Temperature (20^0C)
Frog #1	0.05	0.30 ml O2 / hour / gm
Frog #2	0.03	0.28
Frog #3	0.04	0.25

Procedure

- Calculate the average metabolic rate for the three frogs at each of the two temperatures.
- Put a dot on the graph in Figure 8.11 for each of the average values.
- Draw a line between those two dots.
- Write the word ectotherm on the line.

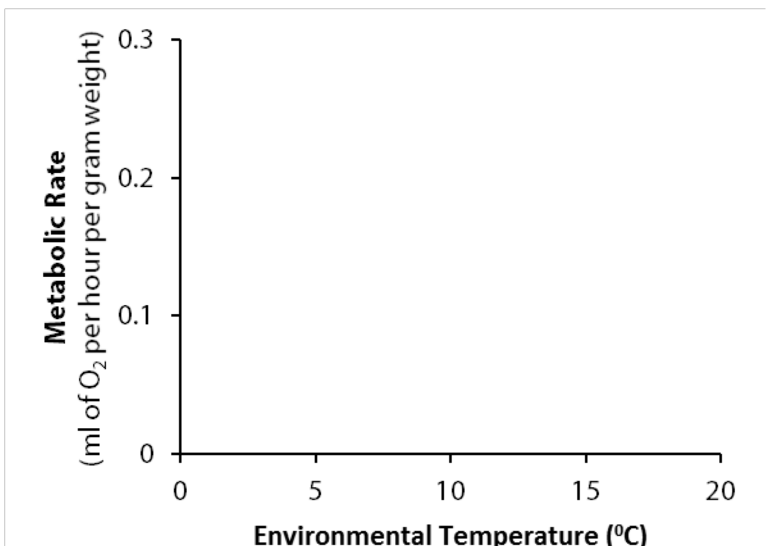


Figure 8.11. Effects of environmental temperature on the metabolic rate of an ectotherm (frog).

? Question

1. Which organism has the slower rate of respiration?
   endotherm or ectotherm

2. Which organism needs less food to survive?
   endotherm or ectotherm

3. How much food does the ectotherm need compared to the endotherm? Hint: Divide metabolic rates.

4. Which organism would do better if the amount of food is very limited, but the environment is fairly warm?

5. What kind of environment is described by question #4?

6. Which organism would do better in a cooler environments where the food is plentiful?
   endotherm or ectotherm

7. Will the organism in question #6 do fine in warmer environments if the food is plentiful?

   Why or why not?

Exercise #5
Food Demand for Humans

How much food does a student need to survive one hour of biology lab class?

We can borrow data from experimental research to help us estimate the amount of food that is required to support a human. Our calculations will be based on grams of sugar as the nutrient. Also, notice that the word Calorie is capitalized. When capitalized, this term represents 1000 times the value of a single calorie (not capitalized).

The Caloric demand for food varies greatly for a human depending on activity and environmental conditions. The energy demand might be as slow as 50 Cal per hour during sleep to as fast as 2,000 Cal per hour during extreme exercise. (That high rate of metabolism could be maintained for only about 2 minutes without total exhaustion.) An average student in biology lab class uses about 100 Calories per hour if they aren't walking around.

Information

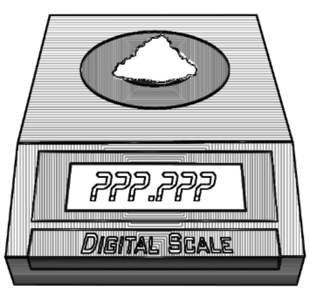
- Assume a food demand of 100 Cal/hour for students.
- A human gets about 4 Cal of energy from 1 gram of sugar.

Procedure

- How many grams of sugar are required to "fuel" an average student during one hour of biology lab class?

  ______ grams of sugar used in one hour

- Weigh out that much sugar and show it to your instructor.



Use a weighing paper or tray for the sugar.

Exercise #6
Dietary Supplements for Increasing Metabolism

"I need something that will raise my energy level but not my self esteem – I'm already full of myself."

The Arguments

Why is Medicine so slow and expensive?

The Supplement Industry has developed alongside the fields of Medicine, Sport, and Nutrition. Its annual revenues in the United States are more than 30 billion dollars. Obviously, many people support its products. What can be said objectively about the health value of these supplements? And what scientific evidence is in support of the claims that they can safely change your metabolic rate?

Medicine's basic approach is to identify serious health problems in patients and to intervene with treatments that eliminate the cause or relieve symptoms. Typically the addition to the understanding of health and disease processes is slow and steady. Medicine is highly regulated, and its focus is on scientific experimentation. Medicine is slow and expensive. There can be a general public frustration of "Why can't they cure me faster and cheaper?"

A very effective marketing tool is to overwhelm the consumer with information from carefully selected research studies, and then add what seems to be reasonable conjecture.

Sport and Nutrition industries are not regulated like the medical fields. This greatly affects how money is spent. The money in these industries is spent on advertisement and promotion rather than on scientific experimentation. Reliability of Sport and Nutrition recommendations is more dependent on the evaluation and judgment of consumers. However, there are several professional organizations and publications that help to debate the validity of claims.

The Supplement Industry is almost completely independent from regulation. This industry does not have to prove that their product is effective. The only requirement is that they must not commit fraud while representing the benefits of their products. This is a legal definition – not physiological or scientific. They can use loosely controlled correlation studies and make claims based on conjecture from known processes. Therefore, you should read their claims very carefully. Examples of misleading statements include:

- Some studies have found …
- Many experts are calling for …
- This supplement makes it easier to …
- A recent study found that …
- You may already know that …, but did you know that …

A primary source of information and claims about supplements is available on the Internet. These sites flood the consumer with misleading information that is not corrected by any regulating agency. Only a few other

"I've got something special for you."

Internet sources (Quackwatch, NCAHF, etc.) attempt to counter the questionable claims. Most of the supplement claims rely on emotional appeal.

- A particular substance is in short supply in your diet – a supplement is needed.
- Take as insurance.
- RDA's (Recommended Daily Allowances) are too low.
- Natural is better than synthetic.
- This way is quick and easy compared to conventional medicine.
- Stress and modern life deplete normal sources.
- Special words are used: cleanse, detoxify, etc.
- Lots of personal antidotes and endorsements.
- Medicine is the enemy – don't trust doctors.

How about Metabolic Supplements?

People want to change their metabolic rate in order to feel better (peppy) or lose weight or to improve physical and mental performance. How much do they want these results? They use illegal substances and go against doctors' warnings, and they risk being discovered by overseeing Sports authorities. Although each metabolic supplement would have to be investigated separately to judge its claims, there are three indicators of whether a supplement might actually change metabolic physiology.

- Does the supplement contain a substance that has been tested by Medical and Academic researchers and shown to have physiological effects?
- Is the supplement being used in the commercial meat industry? If so, it will probably affect human physiology.
- Is the supplement a hormone in a form that actually gets into the blood? If so, it could affect human physiology to a significant degree.

None of these facts tells us that a supplement should be used. Changing physiology is a risky venture. There will be unexpected results and negative side effects. So, is it worth trying to change metabolic rate? The supplement industry says yes, but can we believe them?

What Can We Conclude?

Coffee may be the safe answer.

Metabolic supplements can be divided into four categories: (1) stimulants, (2) thyroid hormone or precursors to it, (3) special elixirs, and (4) an added food nutrient that speeds normal digestion or metabolism. Let's briefly consider some critiques of each category.

There are illegal stimulants that have powerful effects on metabolic rate, appetite, and other neurological mechanisms. These substances have been outlawed because of the addictive properties and damage to the body. Cocaine, amphetamines, and their derivatives head the list of these illegal drugs. The less powerful stimulants are usually legal, and their effects are not as immediately threatening to health. However, the long term effects can compete with those of the powerful stimulants. They usually increase metabolic rate a bit but are more significant in affecting mental alertness. They can be effective in Sport (both endurance and reaction time). Moderate use of some of the less powerful legal stimulants by the general public has not caused serious health concerns. But there are side effects like irritability, sleep disruption, heart arrhythmias, and diarrhea when using these supplements.

Most legal metabolic stimulants have very little effect on metabolic rate. The ones that have some effect include two general categories: (1) those that are from plant extracts or are synthesized copies of certain ingredients in plant extracts, and (2) those that contain small amounts of pharmaceutical stimulants. The best known in the first category include caffeine and all other similar acting stimulants (Guarana, Ginseng, Gingko Biloba, and many others). Ginko Biloba was recategorized from "safe" to "avoid" by the Center for Science in the Public Interest because it contains a toxic substance that induces liver cancer in laboratory mice. All herbal extracts present possible unknown risks. The remarkable fact is that so many consumers would rather pay handsomely for untested and unregulated plant extracts than for known caffeine or theophylline doses (various teas and coffee).

Or, maybe not.

The second category of stimulating supplements are those that contain various amounts of pharmaceutical drugs like ephedrine (MaHuang and Ephedra Sinica), sibutramine (slimming teas), and methylexaneamine (added to geranium oil and other products). The proper discussion of these stimulants would require a course on pharmacology. Consumers use these supplements as a way to avoid doctor and prescription costs, but they risk the side effects from mistaken self-diagnosis and lack of dosage and quality control.

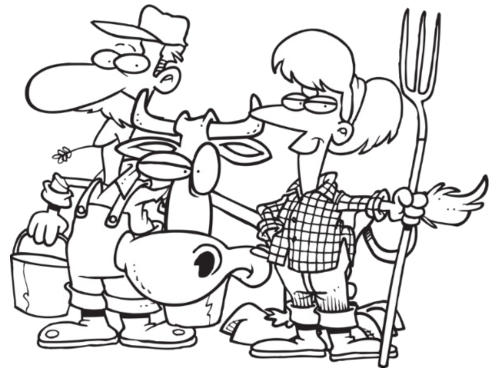
Other metabolic supplements contain hormones or precursors to them. Steroids and growth hormones are a significant part of the Supplement Industry, but they do not affect metabolic rate much at all. The hormone supplement that does increase metabolic rate is thyroid hormone which is a

major controller of the metabolism of fats and carbohydrates. Its effects are profound, and it is a major ingredient in supplements that do stimulate metabolism. Supplement names include: metabolism booster, fat burner, thyroid helper, hyper shred, and many other similar variations. Most thyroid supplements contain thyroid extracts, and their recommended dose is nearly three times what a clinical patient usually starts with as treatment for hypothyroid. The prospective customer uses self-diagnosis with a questionnaire on the Internet, but only 10% of people over the age of 50 have a somewhat low thyroid hormone, and most of those receive something other than thyroid prescription when treated by the Medical professions. There are potent side effects of thyroid overdose including heart damage, anxiety, and thyroid disease itself. Some thyroid supplements contain iodine which is necessary for the natural synthesis of thyroid hormone in the body. But the amount of iodine needed to make normal levels of thyroid hormone is already supplied in a healthful diet, and there are negative side effects of excess iodine in the diet. All of these consequences are risked when using thyroid supplements.

There is another supplement category that could be more accurately called special metabolic elixirs. They are heavily marketed and have no supportive evidence except personal testimonies. The usual claim portrays them as treating nearly every ill of mankind, and they typically contain B vitamins, caffeine, or something else with a recognizable name. Any metabolic rate effect associated with them is accounted for by the placebo effect.

What about special food supplements that claim to improve digestion or increase metabolic rate? We know that a healthful diet is necessary for success in any health or sport endeavor. (That diet is described in the Diet Labs.) Special supplements have not been proven to surpass the benefits of the basic healthful diet. Of course, there are known modifications of diet (more of certain foods) that are important when a person has high levels of physical demand or is trying to lose weight.

We end of our discussion with a repeat of the known metabolic effects of exercise. The most powerful way to increase metabolic rate is to increase physical work. Some training methods are more effective than others, but the main factor is how much exertion you do. All of the illegal substances and most legal supplements have negative side effects, and no supplement effect on metabolic rate compares to a healthful diet combined with physical activity. Furthermore, physical exercise and good diet are free. Our best advice is to skip the supplements.



If farmers are using a particular supplement, it would probably have a physiological effect on you. But, what effect is another question.

? Question

1. Which industries have academic and governmental oversight and regulation?

   Medicine
   Sport
   Nutrition
   Supplement

2. Where is most of the money spent in the Medical Industry?

   Research and Testing
   or
   Advertising

3. Where is most of the money spent in the Supplement Industry?

   Research and Testing
   or
   Advertising

4. List three indicators that a supplement might actually change metabolic physiology.

5. List four general categories of metabolic supplements.

6. Which supplement type has the most powerful effect on metabolic rate?

7. What are the risks using those supplements?

8. What factor will increase metabolic rate many times more than any supplement?

Group Discussion

Discuss the following questions in your lab group.

1. Go on the Internet and search for "metabolic rate supplements". What are the three dominant themes?

2. In your lab group's opinion, what is the strongest argument against using supplements for increasing metabolic rate?

3. In your lab group's opinion, what is the strongest argument against the views presented in this Exercise?