Name

Carbon Monoxide Health Effects – Vocabulary

Use web resources to define the following terms:

Ligand:

Cooperative Binding:

Hemoglobin:

Oxygen:

Carbon Dioxide:

Oxyhemoglobin:

Carboxyhemoglobin:

Pulmonary Respiration:

Hypoxia:

Chemical Affinity:

Sickle-cell Anemia:

Mendelian Genetics:

Teacher Comments:

Name

LAB 1: WHAT ARE THE EFFECTS OF DIFFERENT GASES ON THE COLOR OF BLOOD?

View the short video on the effects of carbon dioxide and carbon monoxide on the blood then answer the following questions:

What is the importance of an experimental control?

Make some observations:

Describe any differences between the control sample and the sample treated with O_2 (tube #1).

Describe any differences between the control sample and the sample treated with CO_2 (tube #2).

Describe any differences between the sample treated with O_2 (tube #1) and the sample treated with CO_2 (tube #2).

Question:

Why do you think the blood treated with O_2 looks different from the blood treated with CO_2?

Make some predictions (CO_2 + O_2):

Do you think there will be a difference in the color of the blood first treated with CO_2 and then with O_2 when compared to the control blood or the samples treated with CO_2 or O_2 alone? Why or why not?

Here are all the options:

Blood + CO_2 + O_2:

Blood + CO_2 only:

Blood + O_2 only:

Make an Observation:

Describe any differences between the samples treated with CO_2 and O_2 alone compared to the sample treated first with CO_2 followed by O_2. Did your predictions match these results? Can you explain what is happening to cause the change to the color of the blood?

Make a prediction about CO Exposure:

We're going to compare the blood we previously examined to blood treated with CO. Do you expect any differences? Why or why not?

Here are all the options:

Blood + CO_2 only:

Blood + O_2 only:

Blood + CO only:

Make an observation:

Describe any differences between the previous samples and the blood treated with CO.

Question:

Did your predictions match the actual results? Can you explain what is happening to cause the change in the color of the blood?

Make another prediction about CO exposure:

We're going to compare CO treated blood with blood that has also been treated with CO_2 or O_2. Based on what you have already observed, do you think you will see any differences in the blood that has been first treated with CO compared to blood treated with CO and then with CO_2? What about blood first treated with CO and then O_2? Why or why not?

Here are all the options:

Blood + CO + CO_2:

Blood + CO + O_2:

Make an observation:

Describe the differences observed between samples treated with CO, CO + CO_2, and CO + O_2.

Questions:

Did your prediction match the actual results?

Can you explain what is happening to cause the change in the color of blood?

Can you predict what the possible consequences might be to your cells' energy-producing abilities if you are exposed to carbon monoxide?

Make some observations:

Describe the overall differences in color between all of the blood samples.
Here are the options:

Control:

Control + O_2 only:

Control + CO_2 only:

Control + CO_2 + O_2:

Control + O_2 + CO_2:

Control + CO only:

Control + CO + CO_2:

Control + CO + O_2:

Question:

Why does the color change when the blood has been exposed to both CO_2 and O_2, but remains the same after exposure to CO? Can you explain what is happening?

Question:

Based on the observations made in this video, can you draw any conclusions about the binding strength between hemoglobin and O_2 compared to hemoglobin and CO? Explain.

Bonus Questions:

Can you explain why a person suffering from carbon monoxide exposure often has cherry-colored skin?

What do you think exposure to carbon monoxide does to your ability to generate energy from the food you eat?

This experiment is missing an example of blood that has been treated with CO2, followed by CO. Can you predict the color of blood that has been treated in that way?

Teacher Comments:

COMPREHENSION 1

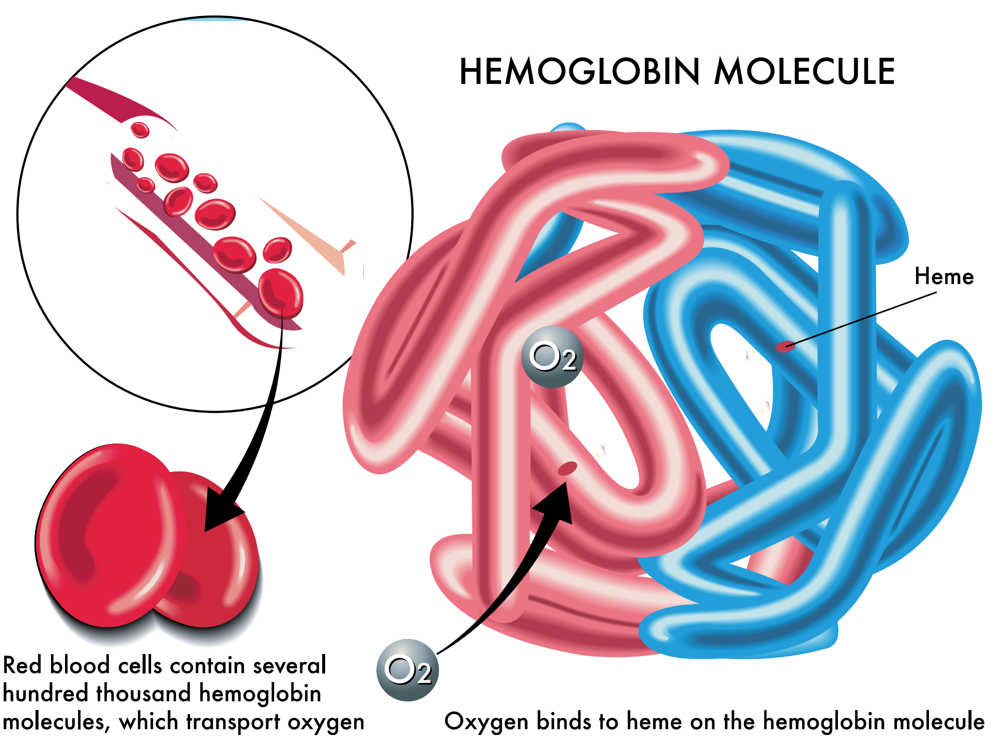
What are the Health Effects from Exposure to Carbon Monoxide?

WHAT IS CARBON MONOXIDE?

Carbon monoxide is a colorless, odorless, tasteless, highly poisonous gas that is slightly less dense than air and is formed from the incomplete combustion of carbon or a carbon-containing material such as gasoline. In addition, carbon monoxide is produced in low levels through the metabolic processes of animals. In the atmosphere, carbon monoxide is short-lived and plays a role in the formation of ozone. Chemically, carbon monoxide consists of one carbon and one oxygen atom that are connected by a triple bond.

WHAT IS HEMOGLOBIN?

Hemogloblin is the red protein found in the blood of animals that is responsible for the delivery of oxygen from the lungs to the rest of the body and for returning carbon dioxide to the lungs to be exhaled. In adults, hemoglobin is formed by the connection of four globulin chains. In the center of each globulin molecule is a heme complex, which contains iron. It is the iron found in the heme complex that enables the transport of oxygen and carbon dioxide through the blood. Iron is also the component of hemoglobin that results in the red color of blood. The presence of hemoglobin in the blood increases its oxygen-carrying capacity seventy-fold more than if oxygen was simply dissolved in the blood. This is because each molecule of hemoglobin is able to carry 4 molecules of oxygen.



WHAT IS CARBOXYHEMOGLOBIN?

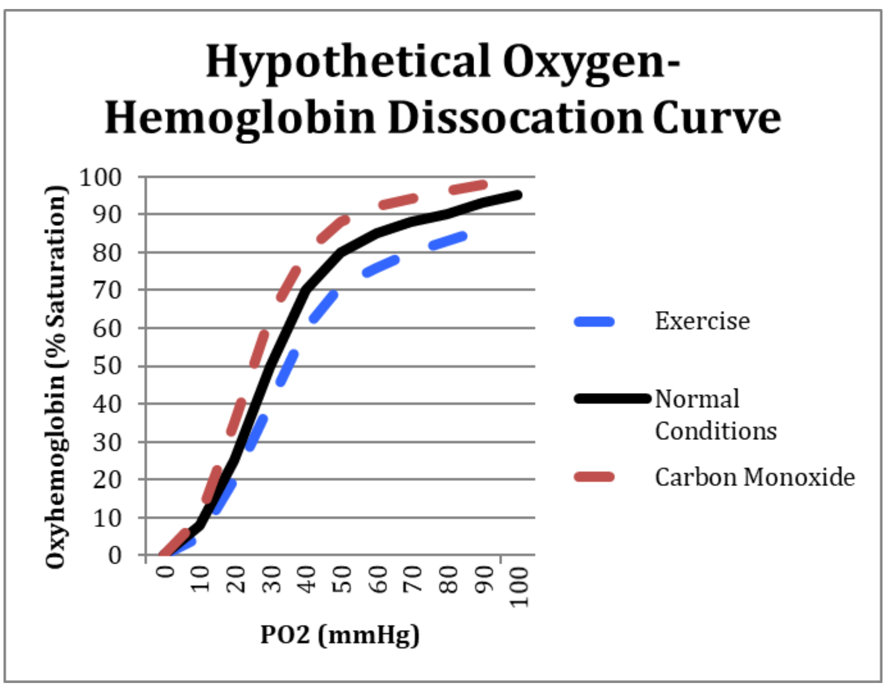
Carboxyhemoglobin is a stable compound that is formed through interaction of carbon monoxide and hemoglobin. Formation of carboxyhemoglobin can occur following the production of carbon monoxide from normal metabolic processes or from exposure through external sources. Carboxyhemoglobin formation results in an inability of the hemoglobin to carry oxygen from the lungs to the rest of the body.

WHAT IS THE RELATIONSHIP BETWEEN CARBON MONOXIDE EXPOSURE AND HYPOXIA?

Exposure to carbon monoxide prevents delivery of oxygen from the lungs to the body tissues via two mechanisms. First, formation of carboxyhemoglobin prevents oxygen from binding to the hemoglobin, reducing the oxygen carrying capacity of the blood. This is due to the high affinity of hemoglobin for carbon monoxide, which is much higher than for oxygen (by a factor of approximately 240:1). Furthermore, the presence of carboxyhemoglobin in the blood shifts the oxygen-hemoglobin dissociation curve to the left. A shift in the dissociation curve means that the remaining oxygen-carrying hemoglobin cannot "deliver" the oxygen to the body tissues as easily as before carbon monoxide exposure. So, the blood cannot carry as much oxygen and it is more difficult to deliver the oxygen that it does carry. As a result, the tissues are starved for oxygen and become hypoxic.

WHAT IS THE OXYGEN-HEMOGLOBIN DISSOCIATION CURVE?

The oxygen-hemoglobin dissociation curve is simply a graph depicting the percent saturation of hemoglobin at differing partial pressures of oxygen. At high partial pressures of oxygen, such as that found in the lungs, hemoglobin binds to oxygen to form oxyhemoglobin. As the blood travels to the many tissues of the body the oxygen dissociates—leaving hemoglobin free to



return to the lungs. The oxygen-hemoglobin dissociation curve is a sigmoidal shape due to the cooperative binding properties of oxygen to the four polypeptides of hemoglobin. This means that hemoglobin's affinity for oxygen increases after it has bound its first oxygen molecule. Therefore, hemoglobin is most attracted to oxygen when three of its four polypeptide chains have already bound to oxygen. Also, there are various factors that can cause the curve to shift to the left or right. For example, carbon monoxide causes the curve to shift to the left (see figure above). This leftward shift indicates that the hemoglobin has an increased affinity for oxygen, however the oxygen is bound more tightly and cannot dissociate as easily to be deposited in the tissues. In contrast, a shift to the right increases the oxygen delivered to the tissues when it is most needed, such as during exercise.

HOW DOES NORMAL PULMONARY RESPIRATION WORK?

Pulmonary respiration is the process by which we breathe in air through the lungs, transport oxygen throughout the body and finally exhale the waste products, primarily carbon dioxide. The breathing movement, which involves both inspiration and expiration, is an active process that primarily uses the contraction of the diaphragm to create a negative pressure in the upper chest cavity, which expands the lungs and draws in air. Conversely, exhalation occurs when the diaphragm relaxes. During periods of forced inhalation or exhalation (such as blowing up a balloon), the intercostal muscles are used to augment the functions of the diaphragm. Once oxygen is inhaled, it binds to hemoglobin within the blood and is carried throughout the body through a series of vessels that get progressively smaller. The smallest of these vessels, the capillaries, branch out into all areas of the body, supplying the organs, glands, and other tissues with a constant supply of oxygen. This oxygen is used by cells in the process of cellular respiration, which converts larger molecules of glucose from the food we ingest into usable energy in the form of ATP. Carbon dioxide is a by-product of cellular respiration that enters the blood stream and is carried by hemoglobin back to the lungs where it is exhaled. The water created in cellular respiration leaves the body via perspiration or urine. The following is the formula for cellular respiration:

$C_6H_{12}O_6$ (glucose) $+6CO_2 \rightarrow 6CO_2 + 6H_2O$ + Energy (ATP)

The exchange of oxygen and carbon dioxide between the blood and the cells of the body is due to differences in the partial pressure of arterial (oxygen rich) and venous (carbon dioxide rich, or oxygen poor) blood.

WHAT ARE THE SYMPTOMS OF CARBON MONOXIDE EXPOSURE?

According to the Centers for Disease Control and Prevention (CDC), the most common symptoms of carbon monoxide exposure include: headache, dizziness, weakness, nausea, vomiting, chest pain, and confusion.

High levels of CO inhalation can cause loss of consciousness and death. Furthermore, one can die from CO poisoning before ever experiencing symptoms. These symptoms are similar to those observed in individuals suffering from oxygen deprivation because both situations are caused by a lack of oxygen being delivered to the various tissues in the body.

WHAT ROLE DOES GENETICS PLAY IN THE FUNCTIONING OF HEMOGLOBIN?

Some people carry a gene that encodes for an abnormal hemoglobin molecule that forms a sickle shape rather than the disc-shape of normal hemoglobin.
The sickle-cell trait is recessive so people with two copies of this gene (i.e., one from each parent) have the disease called sickle-cell anemia. If only one copy of the gene is carried, then the person is known as a carrier of the sickle-cell trait, but does not have sickle-cell anemia. The inheritance pattern for sickle-cell anemia follows typical Mendelian genetics, which means that if only one parent is a carrier of the sickle-cell gene then only half the of the offspring will likely be carriers of the gene; whereas if both parents are carriers of the sickle-cell gene then every pregnancy has a 25% probability of a normal child, 50% probability of a child who carries the gene but is without the disease, and a 25% probability of a child suffering from sickle-cell anemia. In addition, children with sickle-cell anemia have been found to have higher levels of carboxyhemoglobin than their normal counterparts. The sickle cell gene has a higher incidence in certain segments of the population. In the United States, 7-9% of individuals of sub-Saharan African descent are found to carry the trait and approximately 1 out of 500 of these African Americans are afflicted with the disease.

WHAT ARE THE PRIMARY SOURCES FOR CARBON MONOXIDE IN THE ENVIRONMENT?

In the home, the combustion of fuel for heating and cooking is the primary source of carbon monoxide. An improperly maintained or blocked chimney or furnace can allow carbon monoxide to enter the home. Similarly, carbon monoxide can enter the home from the garage when a car, lawn mower or other engine is in operation. Gas stoves and ranges can also be a significant source of carbon monoxide if they are not operated correctly.

In the ambient environment, motor vehicles produce about 60 percent of carbon monoxide nationwide; in cities, it may be as high as 95 percent. Other sources include industrial processes, non-transportation fuel combustion, and wildfires.

Tobacco smoke and the resulting second hand smoke are also a significant source of carbon monoxide. Blood carbon monoxide levels are ten times higher in smokers than in nonsmokers. Although smokers do not generally suffer from true carbon monoxide poisoning, their hemoglobin's ability to transport and release oxygen is still adversely affected causing the heart to work harder in order to move adequate oxygen to the tissues.

WHAT ARE THE BEST PREVENTIVE MEASURES FOR PREVENTING CO POISONING?

The CDC recommends the following to prevent CO exposure and poisoning:

- Call a qualified technician to check your heating system, water heater and any other gas, oil, or coal burning appliances. Do this on a yearly basis.
- Do not use portable flameless chemical heaters (catalytic) indoors. Although these heaters do not have a flame, they burn gas and can cause CO to build up inside your home, cabin, or camper
- If you smell an odor from your gas refrigerator's cooling unit have an expert service it. An odor from the cooling unit of your gas refrigerator can mean you have a defect in the cooling unit. It could also be giving off CO.
- When purchasing gas equipment, buy only equipment carrying the seal of a national testing agency, such as the CSA Group.
- Install a battery-operated or battery back-up CO detector in your home and check or replace the battery when you change the time on your clocks each spring and fall.

Additional measures to prevent CO exposure and poisoning:

- **Don't** use a generator, charcoal grill, camp stove, or other gasoline or charcoal-burning device inside your home, basement, garage, or near a window.
- **Don't** run a car or truck inside a garage attached to your house, even if you leave the door open.
- **Don't** burn anything in a stove or fireplace that isn't vented.
- **Don't** heat your house with a gas oven.

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CO Health Effects Comprehension 1
Guiding Questions

1. What is the primary biological function of hemoglobin?

2. What is cooperative binding?

3. What properties make carbon monoxide of particular concern to public health officials?

4. What happens to the oxygen-carrying capacity of blood after carbon monoxide exposure? Why?

5. In your own words, what is carboxyhemoglobin and why is it important?

6. Examine the Oxyhemoglobin Dissociation Curve. Explain the shifts from the normal conditions curve demonstrated by the carbon monoxide and exercise curves.

7. What are the symptoms of carbon monoxide exposure and why do they make sense given the mechanism of action of carbon monoxide poisoning?

8. What is the relationship between pulmonary and cellular respiration?

9. Describe how carbon monoxide exposure interferes with normal respiration, and how that in turn interferes with cellular respiration

Teacher Comments:

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CO Health Effects: Evaluation Questions

For questions 1-5, place the letter of the best answer in the space before the question.

_____1. What is the name of the condition where oxygen levels in the tissues fall below physiologically required levels?

A. asphyxiation B. pulmonary embolism C. carboxyhemoglobin D. hypoxia

_____2. Which of the following gases will make blood a dark red color?

A. oxygen B. carbon monoxide C. carbon dioxide D. all will make blood dark red

_____3. The heme- in hemoglobin refers to the presence of _____ metal in hemoglobin.

A. calcium B. copper C. iron D. magnesium

_____4. Carbon monoxide can only be reliably detected by technological instrumentation.

A. true B. false

_____5. Hemoglobin has the highest bonding affinity for

A. oxygen B. carbon monoxide C. carbon dioxide D. there is equal affinity for each

Answer the following questions completely and concisely using complete sentences.

As you recall, the color of blood is largely determined by the type of hemoglobin-blood gas complex and the manner in which that complex absorbs light. Examine the data in the table below relating blood color to gas exposure then use the data to answer questions 6-8 below:

Table 1: Blood Color Compared To Gas Exposure

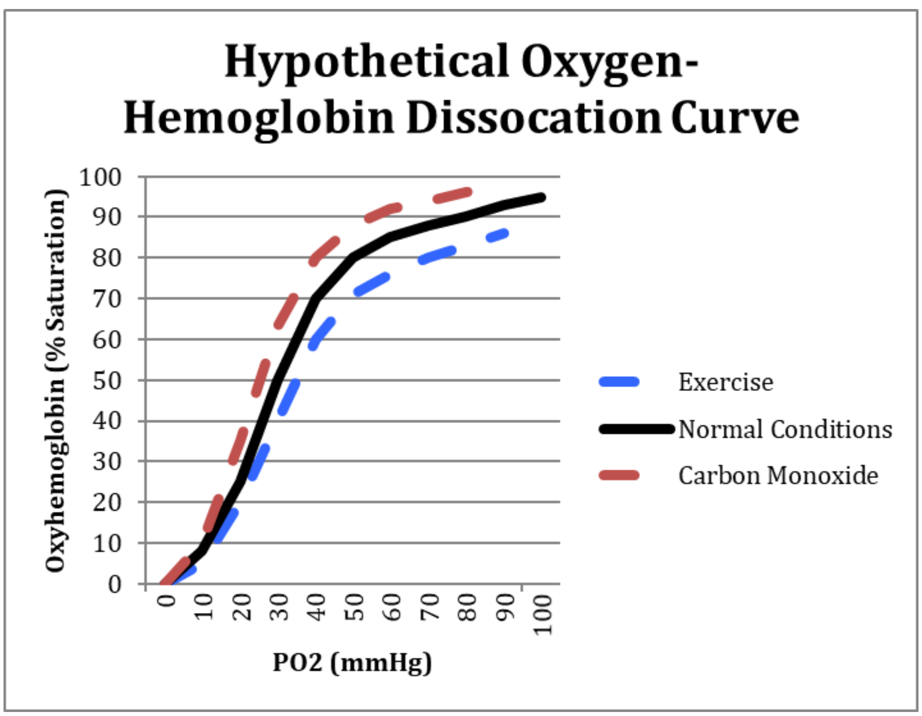
Gas	**Blood Color**
Oxygen	Bright red
Carbon monoxide	Bright red
Carbon dioxide	Dark red
Carbon dioxide then oxygen	Bright red
Carbon monoxide the carbon dioxide	Bright red

6. Based on the data, does hemoglobin have a higher bonding affinity for carbon monoxide or carbon dioxide? Explain.

7. Examine the data where blood is exposed to carbon dioxide then oxygen. Predict the result if the situation was reversed; the blood exposed to oxygen then carbon dioxide.

8. Predict the result if a blood sample was exposed to oxygen then carbon monoxide. Would you be able to predict which gas has a higher bonding affinity to hemoglobin based on your predicted result? Explain.

Use the Oxygen-Hemoglobin Dissociation Curve to answer questions 9-10.



9. Explain the curve labeled normal conditions as it relates to movement of oxygen from the lungs to the other tissues of the body.

10. Examine the curve labeled carbon monoxide. It is clear that this curve represents oxyhemoglobin that is more saturated with oxygen at the same oxygen partial pressure than the oxyhemoglobin under normal conditions. Explain how the carbon monoxide curve can lead to hypoxia even though it is more highly saturated with oxygen.

11. Why does carbon monoxide exposure have similar symptoms to suffocation?

12. Why should a house that has gas appliances or is heated by a combustion processes, gas furnace or wood burning stove/fireplace, have a carbon monoxide detector?

Teacher Comments: