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Relating Air Quality and Prevalence of Asthma in Children

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Overview

This unit intends to look at the impact air quality has on human health, specifically respiratory health. When I was a student in elementary school many years ago, knowing a child with asthma was a rare thing. There were possibly one or two students with asthma in the whole school. Even when I got to high school, I do not recall being acquainted with anyone who had asthma. Now as a teacher, I continue to be startled every year by the number of students with asthma and asthma-type symptoms. Now instead of one or two students in the entire school, it is likely that there is one or two in every classroom. In my particular school this past year, there were 57 students with diagnosed asthma out of a population of 950. There were many more than that with asthma-like symptoms but not an official diagnosis. In the United States, asthma cases nearly doubled between 1980 and 1995. [1] I will be looking at some of the pollution problems in Charlotte, North Carolina where I teach and discuss some of the harmful effects this pollution has on the overall health of our students.

I am designing this curriculum unit to provide a bridge between two very different content units taught as part of the North Carolina seventh grade curriculum. North Carolina is one of only a few states left that has an integrated science content curriculum in middle school. Students have a mix of physical, life, and earth science throughout sixth, seventh, and eighth grade. Seventh grade students begin the year with a unit on atmosphere and weather and then move into a unit on human biology. This unit will help to make a meaningful connection between those two seemingly unrelated topics and to help students see the connections that exist between the various fields of science. We will be looking at the impact of air quality on human health, particularly respiratory health. Every year it seems our general health is more determined by external influences and less so by genetics.

The ultimate goal of this unit is to improve the scientific literacy of my students and make them better citizens who are able to make responsible choices about their environment. I hope to make them aware of ways to protect their respiratory health and help them learn how to understand air quality as it relates to their health. I also want them to be able to make informed decisions when voting on issues and for people who will determine the course our country takes on environmental issues. I want them to understand the impact all individuals have on the amount of pollution in our atmosphere and that continuing to produce as much as we do may have devastating implications for their futures. There are so many types of pollution that affect every part of our Earth and environment that it would be impossible to cover in a unit of this type, so I will be looking

specifically at a couple of types of air pollutants and the type of harm they can cause.

Objectives

The state standards this unit will address include: designing and conducting investigations to demonstrate an understanding of scientific inquiry, demonstrating an understanding of technological design, conducting investigations to build an understanding of the atmosphere. This unit will specifically address evaluating how humans impact air quality. We will also be conducting investigations to explain the effects of environmental influences on human development and explaining how understanding human body systems can help make informed decisions regarding health.

My particular school is a sixth through eighth grade middle school with approximately 1000 students. I teach on an A day/B day block schedule and I typically have 26-32 students in a class, for an average total of 170 students. Middle school science classes in my district are heterogeneously grouped, which means that I can have the highest achievers, the learning disabled, and ESL (English as a Second Language) students all in the same class. This requires a great deal of creativity, differentiated instruction, and lots of planning. This unit will utilize strategies that can be differentiate, used in small groups, and will lend themselves to whole class discussions easily. Science in seventh grade is no longer a state tested subject, so I have a lot of flexibility in how I teach and the amount of time I can give to specific topics. While I am still expected to cover the standard course of study topics, I am not held as rigorously to a rigid pacing guide as other curriculum areas may be.

Introduction

There is a team building activity I do with students sometimes that asks them to prioritize a list of items necessary for survival on the moon. It is rare for students to not choose oxygen as the number one item. It is understood that humans' most basic need is for oxygen. We can live weeks without food, days without water, but without oxygen, survival only lasts for minutes. Unfortunately, the oxygen we need is inhaled along with a multitude of other substances that we not only do not need, but can be harmful to us.

Over the last century, humans have put a countless number of substances into the air which are now a part of the air we breathe. In just 24 hours, our lungs take in 8,000 to 9,000 liters of this air which then meets up with 8,000 to 10,000 liters of blood to begin the run to deliver the all-important oxygen to every one of the trillions of cells in our bodies. The places where this meeting occurs are the alveoli, of which there are about 300 million in an adult lung. Each of these tiny air sacs is surrounded by a capillary that takes on the oxygen in exchange for carbon dioxide.

When we breathe in the gases that are part of the atmosphere, we are increasingly inhaling particulate matter which can lodge in our lungs and create problems even for otherwise healthy people. For people who already have compromised health, the polluted air can be an even bigger threat. For children, the threat gets even worse. Children are at higher risk of respiratory problems due to polluted air for many several reasons.

Children are outside much more than adults. Because of their activity levels they are actually breathing in larger amounts of air than adults. Children in urban areas face the greatest risk of respiratory problems because of polluted air. They are more exposed to vehicle emissions and are often more exposed to factory or plant emissions.

There are many types of pollutants found in the emissions of motor vehicles. I will be focusing on particulate matter as one of the greatest contributors to respiratory problems.

Particulate matter can come in the form of aerosols or solids. The solids vary in size and it is the size of the particle that determines its danger to the human respiratory system. Particulate matter is measured in microns. A micron is one millionth of a meter, so we are talking about matter too small to be seen and therefore difficult or impossible to avoid. Particulate matter (PM for future reference) that is greater than 10 microns normally collects in the throats and noses of people and are normally eliminated by coughing or sneezing. Between 10 microns and 2.5 microns, PM settles in the windpipe. It is the PM that is smaller than 2.5 microns that is the most worrisome. This size of particle can be inhaled deeply into the lungs. It is also happens to be the size of the PM found in fuel combustion and vehicle emissions.

In Mecklenburg County, where Charlotte schools are located, the population has nearly doubled in the past 20 years. The growth has come primarily from the Northeast where an incredibly inflated housing market allowed many moving down here to buy much bigger homes than they previously owned. Charlotte seemed for awhile to have the "bigger is better" mentality when it came to homes and cars. One couple with one child actually built a 35,000 square foot home! This large new number of "McMansions" also had the very large vehicles to go with them. Many times on the roads around Charlotte, there were more SUVs on the road than cars and the great majority of the time, there was one person in the vehicle. Although the population of this county has doubled, the number of miles driven on the roads has **tripled**! [2] Charlotte has had great difficulty in keeping up with this very rapid growth in commuters. In Mecklenburg County, eighty percent of commuters drive alone to work. Only two percent use mass transit and twelve percent carpool. The only public transportation system available up until last fall was a bus system that was not very convenient for people living outside of the center city area. A rail line was finally opened last fall after years of great opposition to it. Some thought the cost was way too great for a mode of transportation they saw as frivolous. There were huge problems with the construction of this rail line, but one corridor was finally opened last fall. The ridership on that one rail line has far exceeded the expectations of everyone which hopefully indicates Charlotteans are ready to get off the highways and into a more environmentally friendly option. The city is now making plans for more lines to open and will hopefully continue to expand this commuting option into farther reaches of the county.

While waiting for Charlotte to embrace public transportation, there are still serious air quality issues to deal with. The air quality problems have been primarily from the large number of cars on the roads in Charlotte. There have been a few days in the past ten years where Charlotte's air quality was worse than Los Angeles, a city with a population many times greater than Charlotte's. The biggest air quality issues for Charlotte are ozone and fine particulate matter (below 2.5 microns). [3]

This unit will attempt to relate the air quality with cases of asthma and other respiratory problems. In addition to looking at the anatomy and physiology of the lungs and respiratory system, I will be showing students the damage that can occur to lungs that are exposed to a constant stream of substances that are not meant to enter the lungs. Dangers of smoking and inhalants may also be looked at as part of this unit. I hope to show students that we are already inhaling many substances that we have no control over. They are present in the outdoors as well as indoors. I will raise the question of "Why would you want to put anything else into your

lungs voluntarily?" We will look at local air quality data on a daily basis during the course of the unit, but will continue to look at air quality throughout the year to compare air quality during seasonal changes and how that relates to asthma episodes. I hope to make students aware that it is not always healthy to exert themselves outside, but indoor activity may be healthier on some days. I also will emphasize that the great majority of our air quality problems are because of cars on the road and try to encourage them to ride bikes when possible and encourage their parents to drive less and look at other alternatives for transportation as well as looking at more efficient cars. Parents sometimes make changes based on information their children bring home. Of course, the high gas prices are forcing changes on many: hopefully change will come not only for economic reasons, but also for health and environmental reasons as well.

The Respiratory System

As part of this unit, I will be focusing on the anatomy and physiology of the respiratory system. How the lungs are structured and how they work is usually a difficult concept for students to grasp. Every time we breathe we bring into our lungs a variety of gases and particles. Before reaching the lungs, these gases and particles must pass through the mucous, hair-covered nose and throat. Many particles not meant to make it to our lungs are trapped there before ever reaching the trachea or windpipe. Those that do make it are brought down the windpipe into two separate bronchi, one to the left lung and one to the right lung. The bronchi separate into tinier and tinier airway passages called bronchioles which end at the alveoli or air sacs of the lungs.

The alveoli are the places where oxygen and carbon dioxide are exchanged in the blood. The blood coming from the pulmonary vein of the heart divides into smaller and smaller capillaries until they are surrounding all of the approximately 600 million alveoli of the lungs. (See Figures 2 and 3) Each alveolus has a radius of about .05 mm. The barrier that exists between the pulmonary capillaries and the alveoli is so thin that oxygen and carbon dioxide and some other gases can diffuse across the barrier. This barrier is only 600-800 nanometers thin and in some places even thinner at 200 nm. At the exchange site, the red blood cell containing hemoglobin releases its carbon dioxide that has been picked up from the body as waste and picks up the oxygen as it goes back to the heart to be sent to the rest of the body. Air entering the alveoli contains approximately 21% oxygen and only .04% carbon dioxide. Air leaving the alveoli has 16% oxygen and 4.4% carbon dioxide. (That 16% oxygen leaving our lungs explains how mouth-to-mouth respiration can save a person who has stopped breathing.) The exchange of gases occurs in fractions of a second and is occurring in all 600 million alveoli. If all of your lung tissue were spread out, it would almost cover an area the size of a tennis court. This amount of surface area through which your body can absorb oxygen is forty times larger than the external surface area of your body. The lungs themselves contain 1500 miles of airways, enough to go from Charlotte to Denver, Colorado! All of the blood vessels in your body could circle the whole Earth two and half times, spreading out to 60,000 miles. Together the respiratory and circulatory systems have a lot of ground to cover which makes the air we breathe so important. Remember we take in 8,000 to 9,000 liters of air every day to maintain a continuous supply of oxygen for the trillions of cells in our bodies.

Asthma

Asthma is a chronic disease that affects the breathing passages and lungs of people who suffer from it. Asthma occurs when the airways of the lungs become inflamed and swollen, and mucus builds up. [4] Mucus is naturally produced by special epithelial cells called goblet cells. The mucus is meant to trap germs and any other foreign material that has entered through the nose or mouth. In asthmatics, the mucus is overproduced. The airways tighten and sometimes close up. This usually occurs in response to a trigger.

Triggers can be a multitude of things, including allergens from dust, pets, or mold. The most common triggers are smog and soot from the tailpipes of cars and from power plants. For most people, the substances we come in contact with can pass in and out of our lungs without causing any ill effects. Sometimes particles are carried away from the alveoli and deposited in the connective tissue of the lungs where it does not necessarily cause harm. For people with asthma, these substances can set off a chain of events that can be very dangerous and even fatal sometimes. The particles that can trigger an asthma attack may irritate the nerve endings in the airways, which leads to muscle contraction and narrowing of the bronchioles. The immune system will mount an attack and send white blood cells unnecessarily and may overproduce mucus, which builds up in the airways and creates an even smaller airway than the muscle contraction and inflammation have already caused. Other triggers for attacks may include cold air, exercise, or stress. An attack can be very frightening for everyone who suffers from them, but it is even more frightening for children. "The worst thing is when you have to go to the hospital. That's what happened to me when I was running around outside, playing with a friend and I didn't take my medicines. We went into his house and his cat triggered my asthma. I had a really bad attack. Now I know if I don't do what I'm supposed to, I'll have an attack, and it's no fun, believe me."(Sky Gardipe, twelve -year-old asthma sufferer) [5] Jackie Joyner-Kersee, another asthma sufferer, said, "It was like a pillow had been shoved over my face. I'll never forget the panic of being completely unable to breathe, no matter how hard I tried." [6]

Asthma is a growing problem in the United States. The prevalence rates nearly doubled between 1980 and 1995. [7] Not only have the rates of asthma increased, but the severity of attacks in affected people has increased. According to the Natural Resources Defense Council (NRDC), there are currently 20 million people with asthma. There are over 5000 deaths per year due to asthma attacks. [8] It is estimated that thirty percent of childhood asthma is now due to environmental factors and that once healthy people are now developing asthma. There is a great difference between children living in urban areas as well as a great difference among ethnic groups. In some urban areas, asthma rates are as high as 23%.

In Charlotte-Mecklenburg Schools (CMS), there are nearly 6500 students with asthma. [9] There is a higher incidence among minority populations and those living in the urban areas. Seventy-four percent of the students with asthma are treated inadequately which results in poor sleep and lack of attention. Asthma is considered a major cause of poor performance in school. Asthma is also the single greatest cause of school absences. In the United States, there are almost 14 million lost school days due to asthma every year. [10] There are 2 million emergency room visits each year due to asthma. Estimates predict these numbers to go up as people are exposed to more and more air pollution. Although the air appears to be cleaner since the introduction of the Clean Air Act in 1967, there are actually more fine particles in the air. There are fewer large particles, but numbers of fine particles which come primarily from car exhaust have increased. The fine particles known as $PM_{2.5}$ are the ones that get inhaled deeply into the lungs and cause the greatest amount of damage to lungs. $PM_{2.5}$ is so small that it can only be seen with an electron microscope. According to the Centers for Disease Control, research has shown that as little as three to five minutes of exposure to particulates from diesel or car exhaust can trigger an asthmatic episode.

It used to be believed that asthmatic lungs would appear normal between the periods of attack. It is now known that asthmatic lungs are nearly always red and inflamed, also known as chronic inflammation. Because of all the unnecessary immune activity in asthmatic lungs, the lining of the airways begins to wear down and break up. This leaves the airways even more susceptible to attack.

Although there is not total agreement whether air pollution causes or exacerbates asthma, the data seems to

provide a clearer picture of the dangers of polluted air for people with respiratory problems, particularly asthma. We can safely make the assumption that reducing exposure to environmental pollutants can help to prevent asthma attacks and reduce the numbers of people developing asthma. Currently, one in ten Americans lives in areas with unhealthful levels of all three types of air pollution.

Vehicle Emissions

In Charlotte, North Carolina, the greatest contributor to our poor air quality is the car. As stated before, the number of miles driven on Charlotte's roads has tripled in the past twenty years, although the population has only doubled. According to the State of the Environment Report for Mecklenburg County for 2008, the greatest air pollution problems for the county are ozone and particulate matter. My students will learn about ozone as a natural part of the stratosphere, but will also learn that ground-level ozone is a pollutant that does not occur naturally. It is formed as a result of a chemical reaction with vehicle emissions and sunlight. The American Lung Association's State of the Air Report 2008 gave Mecklenburg County an "F" for ozone levels. [11] The county had 21 Code Orange Days and 2 Red Days in 2007. Mecklenburg was one of two counties to receive the failing grade. The codes for air quality days are found in the data table to follow.

Air Quality Index (AQI) values are calculated daily for specific monitored pollutants. The pollutants monitored are carbon monoxide, nitrous oxide, ozone, particulate matter, and sulfur dioxide. The pollutant with the highest AQI value is designated as the critical pollutant for that day. Values less than 100 are considered good to moderate and over 100 are considered unhealthy for particular groups. In Charlotte, ozone is usually the critical pollutant in the summer months while particulate matter and carbon monoxide are the critical pollutants during other times of the year. For ozone, the standard is .08 ppm averaged over an eight hour period. In Mecklenburg County, particulate matter ($PM_{2.5}$) is measured with the following two methods:

Particulate Matter PM2.5 FRM: Particulate Matter PM2.5 FRM is the Federal Reference Method for collecting PM2.5 (Fine Particulate) samples. A filter is collected daily and analyzed manually to determine the PM2.5 concentration for the day. Data from this type of analysis is used to determine compliance with the NAAQS (National Ambient Air Quality Standard).

Particulate Matter PM2.5 Continuous: Particulate Matter PM2.5 Continuous (Fine Particulate) is a near real-time method for measuring PM2.5 concentrations. Particulate concentrations are determined automatically by instrumental analysis. This method allows the reporting of PM2.5 concentrations each hour. [12]

The standard for particulate matter is a limit of 35 Mg/m^3 over a twenty four hour period and 15 Mg/m^3 over an annual period. This is then averaged over a three year period to meet the attainment standard for the National Ambient Air Quality Standards. The

following table shows the codes used to indicate daily air quality values. Ozone is typically the pollutant indicated during the summer months.

Air Quality Index(AQI) Values	Levels of Health Concern	Colors
When the AQI is in this range	...air quality conditions are:	...as symbolized by this color:
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for Sensitive Groups	Orange

151 to 200	Unhealthy	Purple
201 to 300	Very Unhealthy	Yellowish orange
301 to 500	Hazardous	Maroon

School Buses

Charlotte is a very large school district that covers a large geographic area. School buses are obviously necessary, but the amount of pollution they add to our atmosphere is hard to do anything about because of their necessity. Charlotte currently has almost 1200 school buses that travel 143,000 miles each day. They transport 85,000 students every school day. Over the course of one year, the Charlotte school buses use 2.5 million gallons of gas and 89,000 quarts of oil. Just with the gallons of gas, school buses in Charlotte are adding almost two million pounds of carbon dioxide into the air. In addition to all of the greenhouse gas the bus is adding, there is also the fine particulate matter that the buses spew out and then come back in to the interior of the bus as the bus makes its stops. In Charlotte, when the new student assignment choice plan was established, five million more miles per year was added to the buses' routes.

In 2007, Charlotte received a grant to buy a hybrid school bus and to have forty particulate filters installed on other school buses. The hybrid school bus doubles fuel efficiency and reduces emissions up to 90%. Charlotte is one of only two cities in North Carolina to get a hybrid school bus. Although the cost is quite a bit higher than regular school buses, the fuel savings and protection of our children's health would make looking into purchasing more hybrid school buses a great alternative to our regular transportation of students. Since orders for hybrid school buses are increasing rapidly, the price for them is also coming down. As part of one of our activities, students will be writing letters requesting more information about the hybrid school buses.

Classroom activities

The classroom activities shared here will follow a unit on the atmosphere and weather where students will have learned about the basic components that make up Earth's atmosphere and will have learned the difference between the ozone that is a natural part of the atmosphere and the ozone created at ground level on Earth primarily due to emissions from motor vehicles. We will have discussed the "bad" ozone as it relates to air quality, but not yet as it relates to human health specifically. The data table above will become a daily part of class through a daily update from www.enviroflash.info which will send a report about local air quality every day.

In addition to the activities that will be listed here, students will have opportunities to make observations of diseased lungs, including ones with emphysema and lung cancer. The pathology laboratory at a local hospital makes available to teachers various organs that have been preserved so students can see the actual parts found inside humans. The organs chosen for observation very often show various disease conditions. Even in a set of healthy lungs, there are very often carbon deposits, which most often occur in city dwellers. I am hoping to schedule a time for the hybrid school bus to come to our school for students to see what it looks like and hopefully give them an opportunity to ask questions about the difference between it and the regular school bus.

Determining Size and Scale

Objective: Students will gain understanding of relative sizes of particles unseen as they relate to substances they can see.

One of the first activities to begin this unit will be to help students understand the size of the harmful particles we are discussing. The terms micron and microgram will be new for them, so to help with the understanding of how small these measurements are, I will use a couple of activities to demonstrate these concepts. Students will have had a very basic introduction to the metric system at the beginning of the year, so they should know the approximate size of a meter and a millimeter. To begin the discussion of the size of a micron, I will have students look at one strand of hair and compare it to the millimeter marking on a metric ruler. After having them estimate the size of the hair, I will share an overhead called "How Big is a Micron?" that shows that a human hair is between 50 and 70 microns compared to a grain of pollen that is 30 to 50 microns. After that initial look at sizes, I will introduce the idea of particulate matter in the air. Figure 1 will be used to help students grasp the general sizes of specific particles. Although students know (after our atmosphere unit) that there are things in the air we cannot see, they still do not quite understand this. I will be using a diffusion activity using water and food coloring to show that as the food coloring is diluted in a systematic way with chem trays, you eventually can no longer see it. Since the students are moving the material, they know there is still a substance in the water even though they cannot see it. This activity would also relate to studies about contaminated water and how much contamination must be present to cause harm. The "Powers of Ten" video will be shown as part of this lesson. This video shows in a very unique way what increasing or decreasing by powers of ten means.

Understanding the Respiratory System

Objective: Students will create drawings and models of the alveoli in the lungs to get an idea of how and where oxygen and carbon dioxide are exchanged.

After a basic introduction to the respiratory system and its structures, students will learn about alveoli as the places where gas exchange takes place. Students will first draw sketches of the alveoli and capillary connection and use color to represent the exchange of gases in the respiratory system. Once drawings are completed and checked for accuracy, students will be asked to create a model of their drawings. They will have the option of working independently or with a partner. They will be given a variety of materials to choose from that can represent the parts they are modeling. After creating their models, students will be asked to share their models and explain why they chose the materials they did.

Airborne Pollutants

Objective: Students will gain an understanding of some of the particulates that are present in the air around the school.

Students will be collecting samples of particulates over a few days time to determine the types of particulates that are present around our school. Students will prepare petri dishes with gridded bottoms so that some quantitative analysis can be done on the particulates gathered. The petri dishes will be lined with a layer of Vaseline, so that they can easily pick up any airborne particles. Students will choose areas around the school where they think the most particulates might be present over a week's time. I will let students brainstorm about places to put the petri dishes, hopefully guiding them toward the bus lot as well as the car pickup area. After several days to a week's time, we will gather the petri dishes and determine if there are any differences

in the types of particulates gathered or any differences in the numbers of particulates gathered. After discussion of the types of particulates present on the petri dishes, I will remind students that the fine particulate matter that is most harmful to us cannot be seen on the petri dishes. However, we can still use the information about the large particulates to infer where the worst fine particulates might be. As a class, we can discuss changes that can be made in the daily routine at school that might reduce student exposures to the worst particulates.

Evil Hitchhiker - Creative Writing Activity

Objective: Students will use knowledge of respiration to create a story of a pollutant as it enters the human body.

Students will write a story about an evil hitchhiker which has attached itself to an oxygen molecule and made its way into the body. The evil hitchhiker will represent one piece of particulate matter that is emitted by a car. Students need to follow the path of this hitchhiker as it makes its way into the body. Students will need to identify all body parts passed on the journey from the time the hitchhiker first enters the body to the time it either exits the body or takes up permanent residence. Students need to create a scenario of what it could do inside the body and how it could affect different organ systems, functions, and normal development.

Persuasive Writing Activity

Objective: Students will write letters to people responsible for transportation decisions in our school system and county and will create plans for reducing the amount of driving time by family members.

In order to promote the idea of students being active participants in society, they will write letters promoting stricter emission controls, better public transportation options, and greener school buses. Students will be given the option of writing to county government officials, state government officials, or to write a letter to their parents and other driving family members about the importance of decreasing driving time.

Students will be asked to keep a record of mileage on their family's main vehicle for one week. After recording that mileage, they will discuss with the family ways to reduce the amount of mileage they put on the car each week. Each family will set a goal and using those numbers, students will use the information about pounds of carbon dioxide produced by a gallon of gas to help families learn how much carbon dioxide they are keeping from the atmosphere by cutting back on driving time.

Endnotes

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1. Storey, Eileen, and Mark Cullen. *A Survey of Asthma Prevalence in Elementary School Children*. Jane Bradley. North Haven, CT: Environment & Health, Inc., 2003.

2. State of the Environment Report, Mecklenburg County, NC, 2008

3. Ibid

4. Bryan,Jenny. *Just the Facts - Asthma.* Chicago: Heinemann Library, 2004.

5. Ibid

6. Ibid

7. Storey, 8

8. www.NRDC.org/air/pollution

9. CMS Asthma Education Program

10. Ibid

11. lungactionlungusadc.org

12. http://maps.co.mecklenburg.nc.us/website/airquality/default.php

Teacher Resources

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EPA, "PM Standards." May, 2008.http://www.epa.gov/air/particlepollution/standards.html (accessed July 20, 2008).

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Storey, Eileen, and Mark Cullen. *A Survey of Asthma Prevalence in Elementary School Children*. Jane Bradley. North Haven, CT: Environment & Health, Inc., 2003

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Appendix

Particle size of contaminants in microns. (www.pecuniary.com)

Figure 1

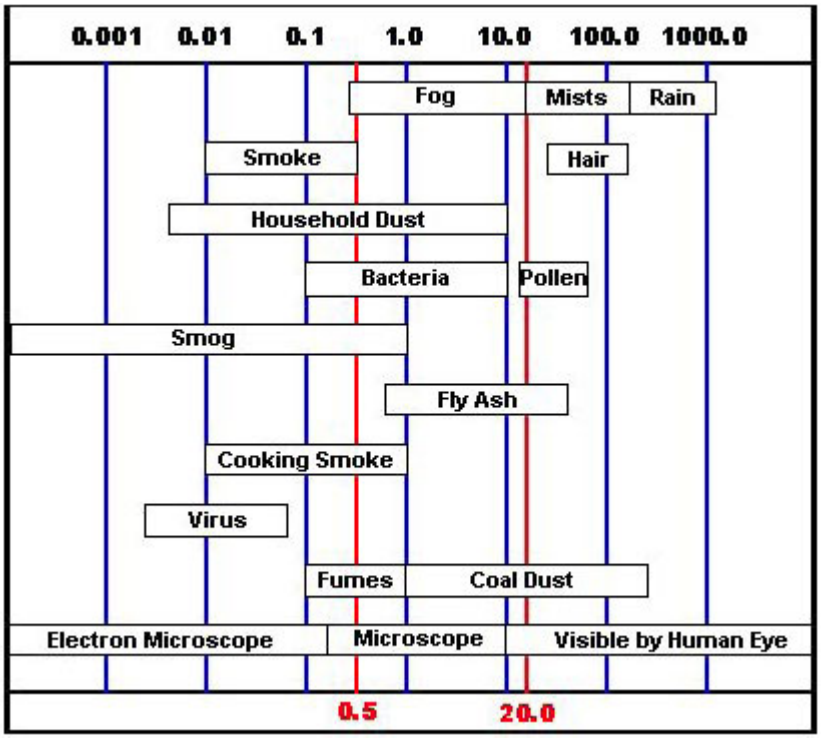


Figure 2

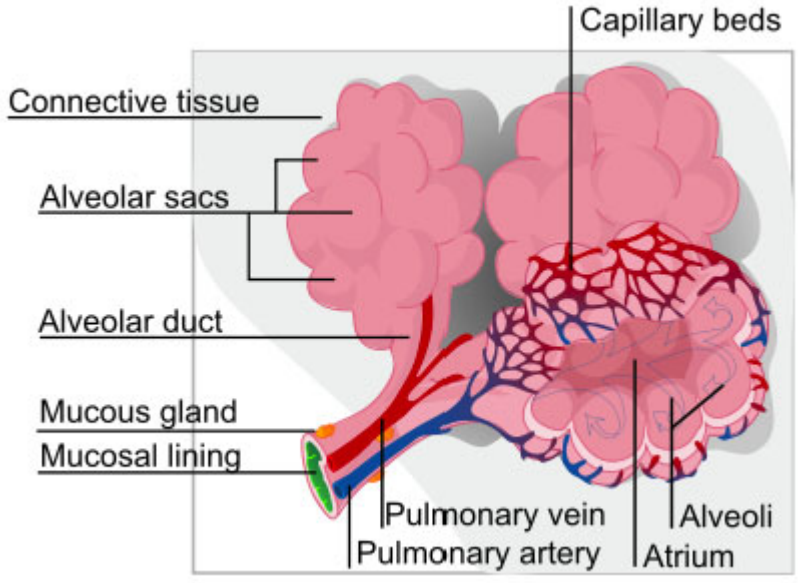
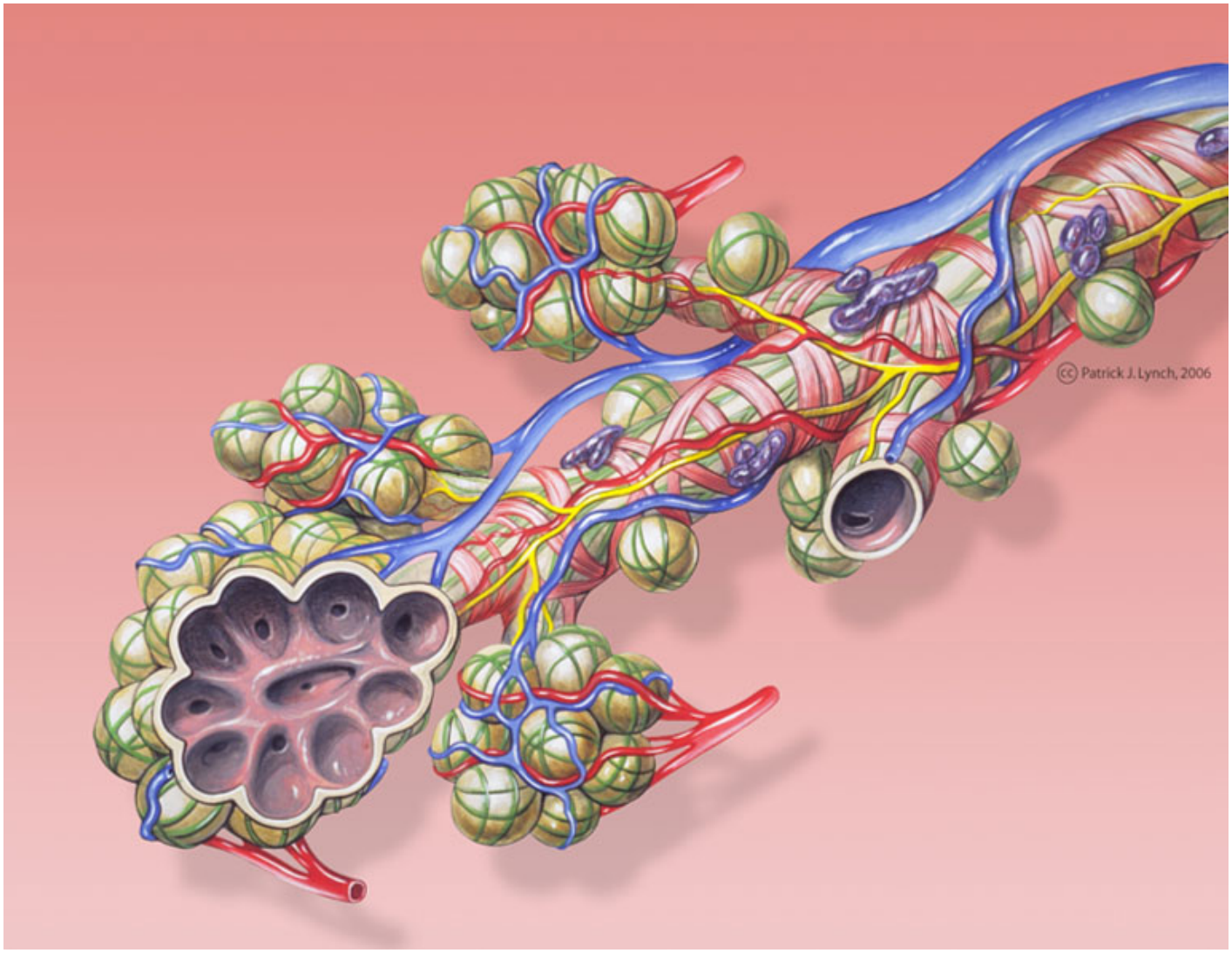


Figure 3



Wikipedia