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Every Breath You Take - Air Pollution's Effects on Respiratory Health

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Introduction

"The potter is covered with earth, although his lifetime is still among the living. He burrows in the field more than swine to bake his cooking vessels. His clothes being stiff with mud, his head cloth consists only of rags, so that the air which comes forth from his burning furnace enters his nose." *The Satire of Trades*, from 12th century B.C. depicts an early account of the environmental conditions that workers face each day in Middle Kingdom Egypt. The account continues to describe a furnace-tender, "His eyes are inflamed because of the heaviness of smoke. He cannot get rid of his dirt, although he spends the day at the reed pond."[1] In the Middle Ages, stories of the plight of workers described how blacksmiths were consumed in rooms full of fumes from furnaces and smoke from metal smithing. During the Industrial Revolution, not only did factories and manufacturing rise, but so did respiratory diseases. Diseases caused by cotton dust, mining smoke, fumes from metal works, and crop dust became more prevalent. By the early mid, 19th century, respiratory diseases like pneumoconiosis, chronic bronchitis, byssinosis, and lung cancer were affecting the masses. Elizabeth Gaskell describes the plight of British cotton workers in the novel *North and South*. "Fluff got into my lungs and poisoned me…little bits fill the air till it looks all fine white dust…it winds round the lungs, and tightens them up. There's many…that falls into a waste, coughing and spitting blood." [2] Air pollution from industry and from the urbanization of cities forced people to breath in air polluted by harmful particles, dust, and chemicals that caused disease. Today, similar problems continue to challenge all nations.

In a CNN report on February 2014, New Delhi, India was crowned the dirtiest city in the world. The World Health Organization reported that in 2014, India's annual average of small particulate matter ($PM_{2.5}$) was 153 micrograms per cubic meter. [3] $PM_{2.5}$ means particulate matter that is very small, only 2.5 micrometers in size. An AQI (Air quality index) of over 100 or $PM_{2.5}$ levels above 35 micrograms per cubic meter signifies that the public should be concerned for their health and safety.[4] China's Beijing was a close second and held the distinction in recent years. In comparison, United States' $PM_{2.5}$ annual average levels only ranged between 7-18 micrograms per cubic meter during the period of 2000 to 2013.[5] Though some countries are making a concerted effort to improve air quality, air pollution is still a global problem. According to WHO, 7 million premature deaths in 2012 were linked to air pollution.[6]

Many nations, including the United States, have strict air quality controls, but developing countries struggle to

enforce changes that could improve air quality. Burns et al. state particulate matter pollution disproportionately affects urban and rural populations in developing countries. One reason for this is the cost of meeting safe air quality levels. The US alone in 2011 spent 65 billion dollars to meet Clean Air Act regulations.[7] The price tag is a steep one to meet for many countries who simply cannot afford to spend billions of dollars regulating air quality. A study by Kanervisto et al. links low socioeconomic status (SES) and chronic obstructive airway diseases. They conclude that the socioeconomically disadvantaged had higher incidences of reporting COPD and asthma. Factors including smoking, physical inactivity, obesity, poor nutrition, lack or little education all contributed to increase reporting of two mentioned respiratory ailments. [8]

Rationale

The heart of the Silicon Valley is San Jose, the San Francisco Bay Area's largest city with nearly 1 million residents. Because the Silicon Valley is known for its high tech industry, it is not surprising that air pollution is an ongoing problem for the growing valley. [9] Along the east foothills lies Mt. Pleasant High School. MP, as it's known in East Side Union High School District celebrated its fiftieth year, having opened its doors to the East Side and Evergreen communities in 1955. Amid the celebrations, many of its past administrators, teachers, and students reflected on its history. Teachers recalled how, in its beginning, Mt. Pleasant was surrounded by orchards, and the major industry was the old Del Monte cannery in downtown San Jose. Before IBM (International Business Machines Corporation) rooted itself in the valley, FMC (Food Machinery Corporation) brought US War Department contracts shifting the major source of economy from agriculture to technology. Today, the tech industry rules the valley and is a major contributor to poor air quality.

The student population of Mt. Pleasant High School reflects that of the city. MP is a diverse school, where the majority of the population is of Latino or Hispanic descent, followed by Asians, Filipinos, African Americans, and Whites.[10] As a Title 1 School, MP students are predominantly come from families that are socioeconomically disadvantaged. The majority of our students (960 out of 1512) receive free and reduced lunch, are labeled ELs (English Leaners). This represents an area of inequality since the average home prices in East San Jose are approximately $700,000. Within the Silicon Valley, there is a disparity of incomes. The typical tech workers receives an average income of approximately $200,000. However, the median income for San Jose is roughly $77,000. Both these numbers do not represent my student's families. The majority of my students' parents can barely afford to live and work in the area, and feed their children. In fact, many of the residents in East San Jose, live well below the poverty line of $24, 250 for a family of four.[11] Because of such inequalities, my students must become advocates not only for their health, but for the health of their family members.

Many of my student's parents work in jobs that support the big tech companies. In their jobs they are exposed to environmental irritants. From gardener, line assembly personnel, house cleaner, to facilities operations, they are subjected to toxic substances and irritants to the respiratory system. For example, a person who cleans houses for a living might be exposed to fumes from various cleaners, dust mites, mold, and mildew. A heating and cooling tech might be exposed to toxic fumes from the refrigerants, and dust and mildew in unclean, unfiltered air in crawl spaces, attics, and basements. Though respiratory safety protocols are taught and practiced, constant and recurring exposure increases a person's chances for developing respiratory disorders.[12]

Content Objectives

As Physiology students, my students understand that one goal I have for them is learn to be advocates for their own health. Often, my 16-18 year old students also become health advocates for their families, since some of their parents have only a middle school or 6th grade education. An ongoing challenge for me is to instill reasons why anatomy and physiology matter beyond my classroom door. Typically, the respiratory system is taught in the early spring, second semester. This unit is intended for presentation after students have learned about immunity. Discussing air pollution and its relation to respiratory health will only help my students apply the content to their daily lives.

The challenge of the Next Generation Science Standards is blending content, engineering, and literacy into the science curriculum. [13] In this unit, students will be able to develop their content knowledge, but apply it to real world problems – air pollution's impact on respiratory health. Through a series of lectures, discussions, classroom debates, student review of current research, and close reading, students in physiology will apply their knowledge to lead an awareness campaign for their peers and community. Through the use of student generated web-pages or blogs, students will highlight issues stemming from air pollution related respiratory disorders. Though this unit is intended for a four week period in Anatomy and Physiology in my classroom, the content and activities can be easily adopted for many Biology or Health Science courses.

Background Content

Air Pollution

Air pollution affects the air we breathe outside our homes, but also affects our lives indoors. This unit will highlight respiratory illnesses that arise at home and at the workplace. Though there are many pulmonary diseases including lung cancer, this unit will cover chronic obstructive pulmonary disease through asthma, restrictive pulmonary disease through silicosis and second-sand smoke from electronic cigarette exposure. It is my intention for students to study a mixture of respiratory ailments that have a long history and those that have recently developed. This broad exposure will introduce them to many concepts in respiratory physiology, and improve their understanding of respiratory health.

The Environmental Protection Agency (EPA) is charged with assessing air quality. The EPA has identified six pollutants in the air as being the most critical and therefore requiring the most attention. They are carbon monoxide, lead, nitrogen oxides, ozone, and particulate matter. Particulate matter varies in size, shape, and source. The Center for Disease Control (CDC) classifies them as being of two major groups: primary and secondary. Primary being the source of the particulate matter and secondary being those that react with sunlight and water to create particles. For example, road dust is a primary source and exhaust from cars is a secondary source. When studying air quality, particles of 2.5 micrometers are measured, since at this size, dust can become trapped in the furthest parts of the lung, the alveoli. There are different types of particular matter, organic and inorganic. Particles like grain, cotton, and animal dander are considered organic because they contain carbon, whereas metals, soil, clay, are inorganic.[14]

According to the EPA many areas of California, including the Sacramento, Central Valley, and San Joaquin Valley violate national ozone and particulate standards. The city of Los Angeles gets the dubious distinction of having the most polluted air among larger cities that include New York, Chicago, and Houston. In fact, one neighborhood, Huntington Park which has a 95% Latino population, became known as “Asthma Town” for its high amount of children with asthma.[15] The reason for the poor air quality in these cities include emissions from industrial sources (factories, refineries, mining, and materials-processing plants), transportation, and power plants.[16] If air pollution were controlled or managed, a 10% reduction of $PM_{2.5}$ would save 400 people in Los Angeles, and 1,500 in California, and 13,000 across the nation.[17]

Since 2014, all of California is categorized as experiencing severe drought conditions, and 70% of the state is categorized as “extreme” or “exceptional” drought conditions. The bread basket of California, once known for its rich agriculture valleys, are turning into the new Dust Bowl.[18] California’s ever increasing drought has changed the once fertile valleys into cracked, dry, and dusty lands. Those left to farm, cultivate, and harvest are exposed to higher levels of particulate matter and dust in the air. Thus, it is understandable that air quality in California will become worse and will lead to further increases in respiratory ailments

Beyond the United States, situations are even worse. In countries like India, parts of Africa, and China smoke from the burning of trash, industrial and vehicular emissions, and coal-fired emissions have clouded the sky and the sun so thick that lung disease, eye disease, and vitamin D deficiency is common place. The similarities of countries with poor air quality include high numbers of people who are impoverished, smoke, obese, diabetic, uninsured, and live in high population density areas.

Anatomy and Physiology of the Respiratory System

There are two types of respiration that occurs in the human body, external respiration and internal respiration. External respiration involved the nasal passages, pharynx, and larynx, trachea, bronchi, and bronchioles, and alveolus. This set of tissues provides for the exchange of oxygen and carbon dioxide between air and blood. Cells within tissues all over the body use oxygen to fuel cellular internal respiration, which leads to carbon dioxide accumulation. Internal respiration is the exchange of gases between the blood and cell’s, either to fuel cells with oxygen or to remove carbon dioxide. [19] This exchange of gases between the body and the external world is the job of the lungs.

The lungs are actually comprised of five lobes (two lobes on the left and three lobes on the right). The five lung lobes and their air passages (trachea, bronchi, and bronchioles) are housed in the thoracic cavity. All the major organs of external respiration lie in this space, including the heart, which is necessary to pump blood which transports the gases from the lungs to the rest of the body. The lungs are surrounded by two membranes, the parietal and visceral pleura. The process of breathing, discussed later, involves a large thin muscle below the lung known as the diaphragm, which separates the thoracic cavity from the abdominal cavity.

The upper respiratory tract includes the structures of the nose, nasal cavity, paranasal sinuses, and pharynx. The first structure of contact between outside air and the human body is the nose and its opening – the nostrils. The nose is divided into two chambers by the nasal septum. As air enters the nose it passes through the nasal conchae, shell like structures that line the nasal cavity. The nasal cavity is more than just a simple passage. This cavity and the nasal conchae increase the surface area for olfactory receptors (smell receptors), hair, blood vessels, and mucous membranes lining the nasal cavity. There, epithelial tissues, (cells lining the cavity) and its goblet cells coat the nose with mucous to create a sticky surface for debris. Similarly, hair

creates a tangled web that can trap dust before entering the upper throat, the pharynx. Blood vessels warm the passing air to body temperature and the olfactory receptors stimulate the brain to create the sensation of smell. [20]

The throat or pharynx is divided into three sections: the nasopharynx, oropharynx, and laryngopharynx. The pharynx leads to the voice box, or larynx. Here, the two sets of vocal cords are housed in cartilage which shape the way sound is produced. Relaxed vocal cords expose the glottis, the hole through which air passes to the main trunk of the respiratory system, the trachea. When food or liquids enter the throat, the epiglottis covers the glottis to prevent food or liquid from entering the trachea preventing choking.

The trachea and lung tissue is analogous to an upside down tree with multiple branches called bronchi. The main trunk, the trachea, is comprised of a series of 20 cartilaginous "C" shaped rings which prevents the air passage from collapsing. Soft tissues between the C-rings allow the trachea to expand. Two main bronchi, right and left, branch off the trachea. These primary bronchi lead to a smaller passages known as bronchioles, which lead to even smaller passages until the bronchioles become alveolar ducts. At the end of each tiny alveolar duct is an air bag, the alveolar sac.[21]

Each alveolar sac is analogous to a grape bundle with many microscopic alveoli. The alveolus is roughly ~ 300 µm in diameter. [22] It is estimated that the human lung contains about 300 million alveoli. Each single cell lined alveolus is wrapped in capillaries, blood vessels that allow oxygen and carbon dioxide to be exchanged. Because of the thin nature of the alveolus and it being the terminal end of bronchial tree, particles from dust, nicotine, and other air pollutants can easily damage the alveoli. The damage can lead to the equivalent of scar tissue, preventing the fragile alveoli from being able to exchange gases with the surrounding blood vessels.

Breathing

As mentioned previously the lungs are surrounded by a membrane, called the pleura. The pleura is actually two layers, one attached to the thoracic wall, the parietal pleura and the other attached to the lung tissue itself, the visceral pleura. Between the two is the intra-pleural space. The process of breathing includes two major processes: inspiration and expiration. In order to understand the mechanism students need to under two basic rules. One, gases move from an area of high concentration to an area of low concentration. Second, according to Boyle's Law, pressure is inversely proportional to volume. Therefore, for a fixed number of molecules at a fixed temperature, any pressure increase corresponds to a decrease in volume. The equation $P_1V_1 = P_2V_2$ describes Boyle's law which can be applied to mechanism of breathing.

To understand how the lungs work students should know the different pressures governing the thoracic cavity. The atmospheric pressure (P_{atm}), the pressure outside of the lungs, is typically 760 mmHg. The alveolar pressure (P_{alv}), the pressure inside the alveoli is also 760 mm Hg if there is no air flow. Intrapulmonary pressure (P_{ip}), the pressure of in the pleural space is about 756 mm Hg. Finally, transpulmonary pressure is difference between the intrapulmonary pressure and alveolar pressure, about -4 mm Hg. This difference in pressure allows the lungs to remain inflated.

During expiration and inspiration the alveolar pressure and the intrapleural pressure change. For example, during inspiration the lung expands: the alveolar pressure drops as alveolar volumes increases. This drop of pressure in the lung creates a gradient (lower pressure in the alveoli compared to outside air), and causes gas molecules to move from the atmosphere into the lungs. Lung volume expansion is created by muscles: the diaphragm drops, the intercostal muscles contract, and the chest rises. The opposite events occur during

expiration, decreasing lung volume and increasing pressure: a gradient of pressure is created (higher pressure in the alveoli compared to the outside air). Responding to this gradient, gas molecules from the lungs, including CO_2, move out into the atmosphere. This movement is created by the rising of the diaphragm and the relaxation of the intercostal muscles, which decrease lung volume. It is important to note that normal expiration is passive process. The relaxation of the intercostal muscles and diaphragm aid to decrease lung volume.

Essentially, breathing is the movement of gases from a region of high pressure to low pressure. The flow of oxygen into the alveolus is affected by the resistance in the respiratory passages like the bronchi and bronchioles. The flow of air is linear with respect to pressure drop as depicted in the equation:

(Equation 1) $\Delta P = VR$, [23]

where ΔP is the change in pressure or pressure difference (gradient of pressure), V is the volumetric flow rate of gas, and R is the resistance to flow.

If resistance in the bronchi were to increase, i.e. constriction of the bronchi, then flow would decrease. Alternate, the pressure gradient required to maintain a flowrate increases as the resistance to flow increases. Other factors also affect alveoli's ability to expand – lung compliance. The ability of the alveoli to change its volume as trans-pulmonary pressure changes describes lung compliance. A decrease in lung compliance, means there must be a greater change in pressure to increase volume. Another factor that influences ventilation of the lungs is elasticity, which is the ability of the alveolar tissue to recoil after being distended. This is affected by surface tension, which resists distension of the alveolus. Essentially, surface tension acts to pull or collapse the alveolus. This force is mitigated by the presence of surfactant which coats the alveoli. Surfactant has both hydrophobic and hydrophilic groups which binds to the water molecules on the surface of the lungs and thus reducing surface tension. The presence of surfactant reduces the amount of pressure the alveoli must overcome to inflate.

At the alveolus, partial pressure of oxygen dictate the movement of the oxygen and carbon dioxide into and out of the alveolus and capillaries (site of gas exchange in the cardiovascular system). Partial pressure of oxygen is the pressure exerted by oxygen (O_2) in a mixture of gases which includes nitrogen (N_2), carbon dioxide (CO_2), and other gases. The changes in concentration of these gases dictate the movement of gases between the alveolus and capillary membrane. When inspiration, or the movement of fresh air into the lung, increases the partial pressure of oxygen within the alveoli, it is equivalent to increasing the concentration of oxygen molecules inside the alveolus. Through the process of diffusion, O_2 moves from the alveolar gas phase into the blood within the capillaries, where oxygen concentrations are lower. During expiration, the CO_2 levels from pulmonary arteries move CO_2 into the alveolus to be expelled.[24] This cycle of exchange is important to understand as it is the mechanism that becomes altered in states of diseases and respiratory distress.

Lung Capacity and Lung Volumes

The amount of gases inside our lungs can be measured using a spirometer, see Figure 1 Lung Capacity. Using this simple machine, lung volumes and capacities can be measured. Total lung capacity (TLC) is the maximum volume of the lungs after maximum inspiration. This volume differs between females and males, with males having a higher TLC. Male TLC is about 6 liters and female TLC is close to 4.2 liters. Vital capacity (VC) is the amount that can be exhaled after maximum inspiration. Residual volume (RV) is the amount of gas left in the lung after max expiration. RV represents about 20% of the TLC. The combination of VC and RV is the TLC. The

rise and fall of the lung volume during normal inspiration and expiration is the tidal volume (TV). This volume ranges between 7% to 8% of the TLC. Inspiratory reserve volume is the amount of air subtracted from the TLC and the TV. Expiratory reserve volume is amount of air available beyond the tidal volume. Functional Residual Capacity is combined volume of the expiratory reserve volume and the residual volume. The vital capacity is the maximum amount of air that can be expired after maximum inhalation.[25] It is important to understand lung capacities and volumes to understand how disease affects our normal gas volume levels.

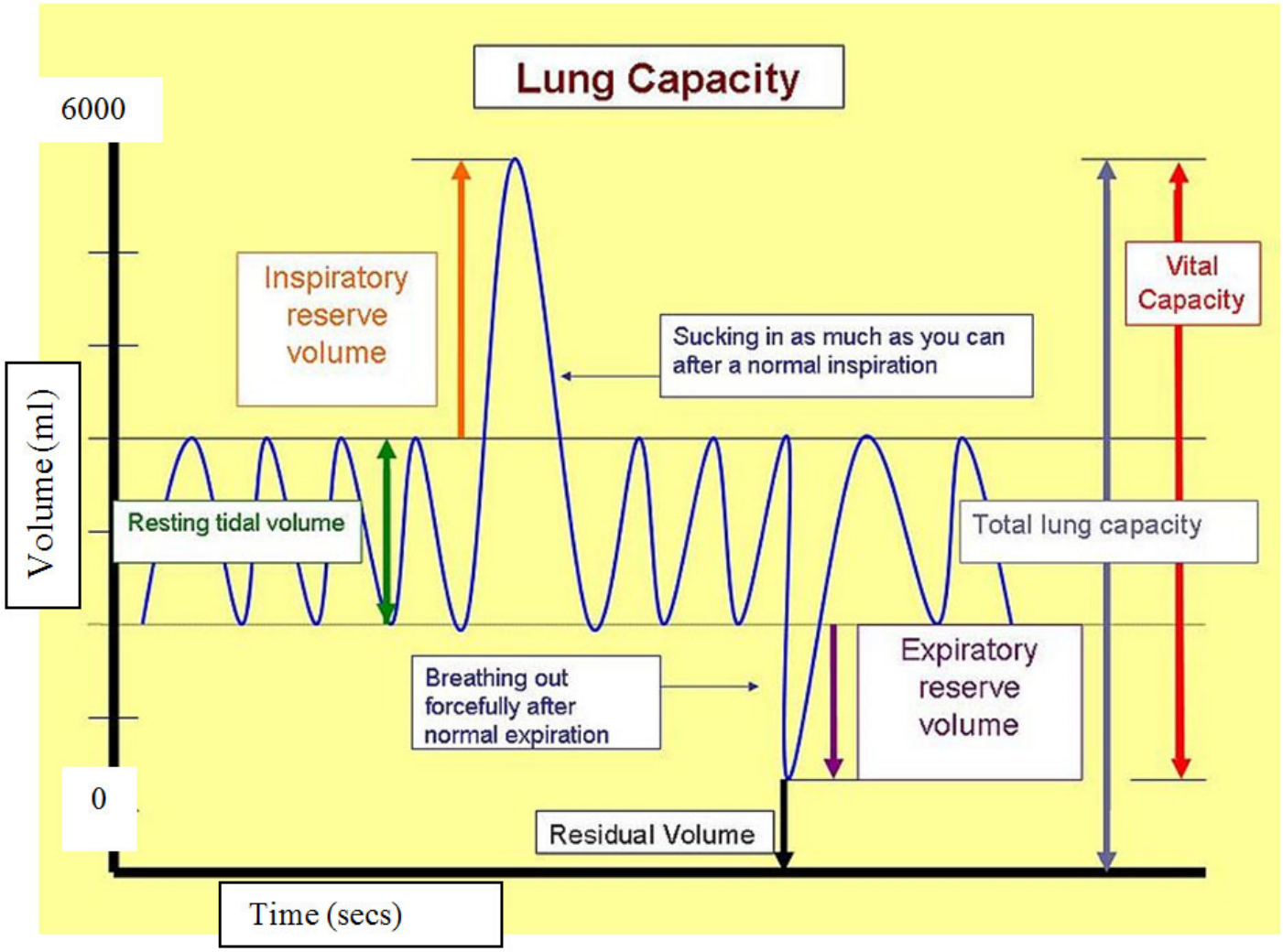

Fig 1: Lung Capacity. [26]

Air Pollution and Obstructive Respiratory Disease

We like to think of our homes as sanctuaries. Inside the confines of our four walls and roof and we build a place of domestic bliss where the hearth warms not only our bodies but fuels it from the food we prepare. In first world countries, this is achieved in safe conditions and we think very little of ill effects of cooking a meal for our families. However, in many other countries, this simple act of cooking can be deleterious to our health and to all those whom we live with.

As of March of 2014, it is estimated that 3 billion people cook over open indoor fires, using solid fuels like wood, animal dung, crop waste, and coal. This daily practice contributes to over 4 million deaths from accidents, COPD (Chronic Obstructive Pulmonary Disease), and lung cancer. Moreover, COPD accounts for

22% of the 4.3 million people who die prematurely from illnesses attributed to household air pollution.[27] Those who cook over open fires are usually in homes that are poorly ventilated and often expose young children to PM particles 100 times higher than what is considered safe. The effects to one's respiratory health include higher chances for developing childhood pneumonia, COPD, and lung cancer.

COPD is the fourth leading cause of disease and death in the United States.[28] Because of its prevalence, COPD, which includes asthma, emphysema, and chronic bronchitis, should be focus in a study about respiratory health. Emphysema and chronic bronchitis are diseases that affect the bronchioles and alveolus. For the purpose of this unit asthma will be the focus since it is a familiar disease to many of my students. Besides inhalation of dust, soot, and smoke, a National Resource Defense Council (NRDC) study of Latinos in Southern California and Mexico border have found that living near freeways and heavy traffic areas increase the number of children with asthma. An interesting fact my students can relate to is that two million Latinos in the US suffer from asthma. NRDC's study concluded that busy urban cities are hot spots for asthma. These include Boston, the South Bronx of New York City, and Chicago.[29]

Asthma is a chronic disorder of the conducting airways, in which bronchoconstriction occurs due to increased sensitivity to various stimuli inciting an allergic attack. Asthma symptoms includes inflammation of bronchial walls and production of mucus.[30] There are two major types of asthma, atopic and non-atopic. Atopic asthma is the most common type of asthma, called type I hypersensitivity. In atopic asthma immune cells become activated usually preceding an already pre-existing condition like rhinitis (inflammation of the mucus membrane) or eczema. In non-atopic asthma, people experience asthmatic episodes due to other triggers like air pollutants and irritants.[31] In large cities pollutants and irritants from exhaust, manufacturing, stress, and everyday chemical irritants can trigger an asthma attack. In low-income countries where cooking is done through an open fire, small particles from the burning of wood, coal, and other fuel sources accumulate in the home and are regularly inhaled contributing to asthma.

An asthma sufferer feels severe dyspnea (labored breathing) and wheezing. During an asthma attack, the bronchi become inflamed with eosinophils (white blood cells that promote inflammation) and mucus begins to build up. The bronchi smooth muscle hypertrophy (increase in size) and increase muscular activity causing intermittent obstruction of the bronchi.[32] As they suffer to force air into the lungs, an asthma sufferer exerts more energy to overcome the constriction in the bronchi. According to the Equation 1, when resistance increases in the bronchi, flow in the bronchial passage diminishes. Asthmatics try to overcome this restriction by increasing their respiratory effort which directly influences ΔP. In reference to lung volumes (Figure 1), asthmatics have a decreased FEV (forced expiratory volume) to FVC (forced volume capacity) ratio and lower vital capacity since asthmatics are unable to move air into the deeper areas of the lungs. Furthermore, compliance in the lung decreases meaning that the elastic ability of the lungs to inflate and deflate are diminished.[33] To counter this effect, inhalers with bronchodilators and corticosteroids help to reduce inflammation and open the air passages and decrease airway resistance.[34]

Air Pollution and Restrictive Lung Disease

Similar to obstructive pulmonary disease, restrictive lung disease prevents the filling of lung tissue. Specifically, it is a pulmonary disease that causes inflammation and fibrosis (thickening or scarring) of the lung interstitial tissue. Interstitial tissue of the lungs includes the lining of the alveoli. Restrictive Pulmonary Disease causes dyspnea, inspiratory crackling sounds, reduced lung volumes, and reduced lung compliance.[35] Conditions like Coal Miner's Lung, Silicosis, and Asbestosis are specific forms of pneumoconiosis. The term

pneumoconiosis is a group of diseases related to the inhalation of small particulate matter to diseased states after a long period of exposure. Typically, these diseases develop in people whose occupation exposes them to environments where the air is filled with dust. Historically, these occupations were stone masons in Egypt. There, workers toiled in desert sands mining and carving giant blocks of stone while inhaling the dust from the stone. Throughout the Industrial Revolutions in England and the United States, workers crowded to big cities and were engulfed by air qualities so poor that many died of lung diseases. Today, industry is more regulated for air pollutants but, workers still face the same issues that their ancestors faced. An example of a restrictive pulmonary disease that continues to affect workers is Silicosis.

Silicosis the most prevalent occupational disease in the world. The condition occurs when workers inhale crystalline silica dust. The silica interacts with epithelial cells and macrophages and create nodules in the lung tissue. In the early stages of the disease, workers do not experience any shortness of breath, but in later stages the nodules become larger causing pulmonary hypertension, chronic hypoxia, and overall pulmonary dysfunction. Because of the disease also causes decreased macrophage count and decreased cell-mediated immunity response, a person with silicosis becomes more susceptible to other diseases like tuberculosis.[36]

Silicosis is caused by dust containing crystalline silica. This mineral can be found in mines, foundries, blasting operations, stone, clay, and glass manufacturing. The silica dust enters the respiratory passages and causes microscopic scar tissue to develop preventing the alveolus from exchanging gases. Patients experience shortness of breath, loss of appetite, chest pains, and respiratory failure. Though few actually die from silicosis, patients become more susceptible to other respiratory disease like tuberculosis according to the National Institute for Occupational Disorders.[37]

Second Hand Smoke and Electronic Cigarettes

Health concerns regarding second hand smoke have been a focus due to the tobacco-use cessation programs over the last thirty years. Unfortunately, the EPA estimates that 600,000 people die of second hand smoke inhalation each year and 40% of children worldwide have been exposed to environmental tobacco smoke.[38] Though tobacco smoking has decreased, in many schools, including Mt. Pleasant High School the prevalence of electronic cigarettes (e-cigarette) and vaping (e-cigarette smoking) is on the rise. Instead of tobacco, an electronic includes a battery, an atomizer (heating element), and cartridge which contains the nicotine containing e-liquid (a mixture of nicotine and propylene glycol). The difference between traditional cigarettes and e-cigarettes is that the user is not exposed to tobacco combustion toxins and other carcinogens during inhalation. Though manufacturers of e-cigarettes initially meant them to help curb nicotine use, e-cigarette popularity is increasing worldwide.

A report by Callahan-Lyon showed that due to limited scientific research available the human health effects of electronic cigarette' vapor are inconclusive. Her review does cite that residue from e-cigarette cartridges (e-liquid) can remain on surfaces for weeks. When chemicals like tobacco-specific nitrosamine (TSNA) mix with nitrous oxide, non-users may become exposed to carcinogens through inhalation, skin contact, or accidental ingestion.[39] TSNA is a carcinogenic chemical found in tobacco products. Since many cartridges are flavored with sweet flavors, children can mistake the e-liquid as liquid candy. These flavors include vanilla, strawberry, cantaloupe, chocolate flavored e-liquids. Exposure to aerosol from exhaled e-cigarettes is less harmful than from tobacco second hand cigarette smoke. Despite the lower levels of aerosolized TSNA, Callahan-Lyon finds that residues of nicotine remain on surfaces for longer periods of time thereby increasing exposure through dermal contact, lung inhalation, and ingestion. Czogala et al. supports Callahan-Lyon's results stating that exhaled vapor from e-cigarette users do expose non-users to nicotine. However the amount of nicotine

exhaled is significantly lower than regular cigarettes. Their study compared different brands of e-cigarettes and showed that they do emit significant amounts of nicotine, but did not emit significant amount of carbon dioxide and volatile organic compounds, which is found in traditional tobacco smoke. As of 2013, very little research had been done to show the correlation of e-cigarette vapors and the health of the most vulnerable population: women, children, and those with pre-existing health conditions.[40] Their findings represent an ambiguity that many students and tobacco users must decipher for themselves. Are e-cigarettes bad for you? Or is it still a better alternative to traditional cigarettes. Though the question can be argued for both sides (for now), it still stands that nicotine, whether inhaled or in contact with the skin, should be avoided especially by children where high levels of nicotine contact can lead to systemic toxicity. And, it is known fact that second hand smoke can lead to COPD, whether it is bronchitis or asthma. Furthermore, studies do show that vaping tends to lead to other tobacco use among teens who use e-cigarettes.[41] Further study and investigation will surely change people's perspective as to the safety of this currently poorly regulated product.

Classroom Strategies and Student Activities

When teachers are evaluated an aspect of their evaluation that new and seasoned teachers often struggle with is Classroom Management. The term is broad and encompasses the skills, techniques, and bag-of-tricks teachers bring to their classroom to keep their students on task, to maintain classroom structure, and to provide an academic setting. Performing a web search of classroom management strategies will lead any educator to millions of web hits. So, how does one choose from this vast pool of knowledge? In my classroom, I've found that one classroom management strategy that almost always works is the one we learn early in our teacher education training – engagement. As long as I am able to engage my students, student maintain behaviors appropriate or the academic environment.

In teaching this unit, the goal and the challenge is to engage students through every lecture, individual and collaborative work, and assessment. When attempting to keep students engaged, I do my best to limit the amount of down-time. If my students feel there is purpose and goal for the hour I have them, I can engaged them from the very moment they enter class. During the hour period, when student's' attention ebbs and flows, I make it a point to incorporate multiple learning modalities. For example, in any given hour students will read a question of interest to the lesson, discuss that question, watch a video to clarify a concept, reflect their understanding through their writing, collaborate as they move and walk with another student, and of course, simply quietly listen when necessary. All these modalities makes for a seemingly maddening and chaotic classroom environment, but it has proven to be an effective strategy for keeping my students engaged throughout the class period.

One activity that keeps my students engaged is a collaborative strategy called Two-line-Pair--Share. In this activity, students face each other and one row of students is denoted as "A" line and the other "B" line. For the purpose of this unit, students will be asked a series of question that they will share with their first partner. For example, "A" line shares their response to the question, "What respiratory problems are you familiar with?" "B" line listens and responds by summarizing or paraphrasing what was said by "A". Then "B" line shares their response to the same question. After both sides have had a chance to listen, respond, and paraphrase, "A" line is asked to move down one person. Thus, A and B now have new partners. A new question is prompted to the students and the activity continues for about fifteen minutes. Appendix A includes

a list of questions that are intended for this unit and this activity.

As my students become familiar with my classroom structure, teaching them a new skill gradually becomes easier. This is, in part, because they have come to trust that I will be prepared for class and will have something for them to learn. One of the new shifts in education is the move towards incorporating literary skills as an answer to the Common Core State Standards. Thus, embedding literacy into the science curriculum has lately become a major focus in our district. Therefore an activity students will engage in will be to review articles, textbooks, and journals to decide whether or not electronic cigarette should be banned from public spaces similar to tobacco cigarettes. A sample list of potential reading material is available in Appendix B. Since Mt. Pleasant is an AVID School (Advancement via Individual Determination), students become familiar with AVID Reading and Writing strategies beginning with their freshmen year. In reading material for this unit, students will utilize AVID's Critical Reading strategies to work through their text. This methodology allows students to employ prior knowledge, close reading, and evaluation as they read for information. This will allow students to practice interacting with their text through the use of annotations, writing and note-taking in the margins, and to reflect on their reading.

As an example, an AVID Critical Reading Strategy involves teaching students six interacting-with-a-text skills. Using a textbook passage or article, students will need to Visualize, Clarify, Respond, Summarize, Connect and Question while reading through a text.[1] Visualization involves students drawing symbols, pictures to depict ideas presented in text. The central question teachers would ask students is, "What visual can we use to depict this concept?" When Clarifying, students are asked to define key terms and paraphrase ideas. In Responding to a text, students note interesting ideas, identify and establish claims, and remark on statements that they find shocking or surprising. Summarizing the text means to restate key paragraphs that support an author's claims. Finally, Connecting and Questioning allows students to relate the material back to themselves, and their prior knowledge. It gives them the freedom to decide whether they are in agreement with the author, discover possible topics for extending their learning, and exposing potential fallacies or biases within the text.

In the last two years teachers throughout our district have been asked to increase the rigor in our classroom by moving students to the higher levels of Webb's Depth of Knowledge. By being cognizant of the types of tasks we ask students to perform, moving through the levels (1-4) becomes more manageable. Though achieving Level 4, Extended Thinking, is challenging, by informing my students of this goal from the beginning I am able to prime them to expect this level of rigor before the unit begins. Moving from Level 1 understanding to Level 4 understanding requires time and constant demand on students to show evidence of their learning. I have found that giving students the autonomy to choose topics within the scope of our unit allows them to move through the succession of levels much faster than forcing my lesson into a specific DOK level. In addition, by choosing broad, multi-variable problems with multiple solutions that are relatable to real life situations, students rise to challenge of the problem because they see the importance of solving the problem and they take ownership of their learning.

The challenge in this unit will be for students to educate others regarding the health risks of poor air quality. Since our goal as a district is to move students through Webb's Depth of Knowledge, I hope their web based readings will lead them to being able to formulate answers that require increasingly deeper understanding of the respiratory system. For my students, this means that they will understand the respiratory system, and also be able to use this information in classroom discussion, debates, and ultimately their culmination project.

After completing their assigned and self-selected activities, students will complete a laboratory activity in

which they use a balloon to illustrate different lung volumes and capacities. Biology Corner has a lab that provides detailed instructions for this activity.[2] Students in physiology will do a similar activity but they will also be asked to create a model lung using a simple soda bottle, straw, and balloons. Though some students have familiarity with this model, the activity will be extended by asking students to experiment with various factors that would decrease the lung's ability to do work. In this lab, students will need to propose the materials they intend to use/change and predict the overall affect and functionality of the lung.

Finally, as a culminating project I intend for my students to discover and use free software applications to create propaganda posters for cleaner, safer air. As a district, we have shifted towards the use of technology in the classroom to familiarize students with various computer applications that can be helpful in their studies and thus projects that encourage technology is highly encouraged. After learning the anatomy and physiology of the respiratory system and reading about the air quality in multiple cities around the world, students will be asked to create a propaganda ad for better air quality in the language of that country. Along with the propaganda ad, students will justify their ad with evidence that expresses the need for cleaner air as it related to the physiology of the respiratory system. This ad will be available through student generated web pages. During presentations, each student's ad will have a QR (Quick Response) code. When the QR code is read by one student's QR reader (a free application for cell phones), it will lead other students' cell phone or tablet to the student-generated web pages. Thus, the class will be able to see respiratory health issues throughout the world and, hopefully, inspire others to change their habits to improve their respiratory health.

Notes

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Appendix A – Two-Line-Pair-Share

Guidelines: This activity can be done after a reading is completed or as the beginning of a lesson. It is a good way to stimulate conversation but to also check for understanding.

Questions to ask Students during Two-Line-Pair-Share

1. Based on your reading, share two facts you've learned.
2. What did you find most interesting or surprising from the reading?
3. What would you like to more about after having completed the task/lesson?
4. After completing (lab, activity, group work etc.) what was frustrating or confusing to you and why?
5. If you could change the (lab, activity, group work etc.) what would you change and why?
6. In your own words, describe what you understand as the function of the lungs?
7. In your own words, describe what you understand as the effects of pollution on your ability respire?
8. What solutions can effects of pollution on your ability respire?
9. What solutions can imagine to combat poor air quality at home and in the workplace?
10. List and describe what factors you believe contribute to poor air quality and in turn poor respiratory health.

Appendix B – Student Reading List for Electronic Cigarette Discussion and Debate

The reading list represents a sample of web-based articles that can be assigned for students to read as they prepare for a discussion or debate. The list includes readings at various reading levels. Scaffolding of the more difficult readings is recommended**.**

E-Cigarettes:

1. "Smoke Screen: Are E-Cigarettes Safe? by Dina Fine Maron. Available at: http://www.scientificamerican.com/article/smoke-screen-are-e-cigarettes-safe/
2. "PRO/CON: Should e-cigs be regulated just like cigarettes? By Tribune News Service, adapted by Newela staff. Available at: https://newsela.com/articles/procon-ecigs/id/8077/
3. "For the poor, cigarettes a salve for hunger pangs and mental woes" by Philadelphia Inquirer, adapted for Newsela staff. Available at: https://newsela.com/articles/poor-smoking/id/1515/
4. "Electronic cigarettes: fact or faction" by Robert West and Jamie Brown. Available at: http://bjgp.org/content/64/626/442. Good article for beginning e-cigarette discussion with students.
5. "E-cigarettes: The lingering questions" by Daniel Cressey. Available at: http://www.nature.com/news/e-cigarettes-the-lingering-questions-1.15762
6. "Family, peers influence teens' e-cigarette use" by Andrew Seaman. Available at: http://www.reuters.com/article/2015/07/27/us-health-teens-smoking-ecigarettes-idUSKCN0Q11YC20150727. Web article that would serve as a good reading for students as they decide the factors that contribute to e-cigarette use.
7. "Electronic Cigarettes (e-cigarettes)" by FDA (Food and Drug Administration). Available at: http://www.fda.gov/NewsEvents/PublicHealthFocus/ucm172906.htm. This is a good starting point for basic information about e-cigarettes.

Appendix C – Implementing District Standards

Next Generation Science Standards (NGSS) includes eight science and engineering practice standards that grow in complexity as students' progress in their in education. The practices reflect what skills students should develop within the scope the course's content. This unit will focus on three of the eight practice standards. All standards are available through the NGSS website.

1. Practice 1: Asking Questions and Defining Problems

The standards state that by grades 9-12 students are able to ask questions and define problems in 9–12 that builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.

In this unit, students are asked to observe a global problem, air pollution and health, and are expected to seek additional informational from their observations. Furthermore, they are encouraged to interpret data, challenge available information in order to deepen their own understanding.

2. Practice 7: Engaging in argument from evidence

Practice 7 in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s).

Arguments may also come from current scientific or historical episodes in science.

In reading and comparing the available literature on e-cigarette use and its relation to respiratory health students will compare and evaluate arguments for or against the use of electronic cigarette for tobacco cessation. In addition, students will evaluate claims, evidence, reasoning from multiple sources while practicing critical reading strategies. During the class discussions and debate they must be able to construct a defense statement for their arguments and provide support for their claims from non-fiction sources.

3. Practice 8: Obtaining, evaluating, and communicating information

Practice 8 in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs.

Similar to Practice 7, this unit allows students the opportunity to critically read scientific literature to determine central ideas and to summarize complex ideas from technical text. Through scaffolding, students will be able to compare multiple sources regarding respiratory health and air pollution and credit the validity of the source by examining the accuracy of the claims in the articles and or videos. The final project allows students to communicate their understanding and level of knowledge regarding the scientific information they have gathered.