Our Forests and Climate Change

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How can we save our "Goldilocks Zone" from climate change catastrophes?

Abstract:

The trees are the lungs of our planet. Among all the planets in our solar system, only Earth is habitable, and heterotrophic life began after the evolution of photosynthetic cyanobacteria and the earliest marine and freshwater algal mats (Knauth & Kennedy, 2009; Strother et al., 2011). With the help of photosynthesis, atmospheric oxygen levels rose, the ozone layer formed, and slowly life began to flourish on Earth. Photosynthesis is the biggest miracle of life on Earth. Via the process of photosynthesis, chloroplasts convert carbon dioxide and water into glucose and oxygen in the presence of sunlight. There are about 100 chloroplasts in each mesophyll layer of leaves (Woodson, 2016). Photosynthesis converts ~200 billion tons of CO_2 into complex organic compounds annually and produces ~140 billion tons of oxygen in the atmosphere (Johnson, 2016). Trees are the soul of our planet Earth, and the only way we will save our future is by stopping the cutting down of trees and preserving our old forests. It is important to grow trees around the hospitals and workplaces, so folks can enjoy forest therapy during lunchtime. Students should have their classes and important learning time in these forest areas. In the first component, I will introduce students to the basic anatomy of plants, plant cells, and the global carbon cycle. Climate change and how trees prevent climate change would be the second component. Can we still restore our forests and stop climate change by educating our students and local communities?

Keywords: Photosynthesis, Respiration, Forests, Forest Bathing, Agarikon, Climate Change

Unit Content

Curriculum Narrative:

Trees play a vital role in our physical, mental, emotional, and social well-being. Trees "eat" greenhouse gases that cause climate change for their breakfast, lunch, and dinner. Trees are not only the source of clean air, trees filter groundwater and surface water, prevent erosion, and also regulate rain, temperature and our seasons not only for humans but also for other plants, animals, birds, and microorganisms that live on or not on trees. They provide a natural refuge to most of Earth's inhabitants and also protect life below or on water and land (Turner-Skoff & Cavender, 2019). Trees promote social and community ties and reduce the crime rate. They also reduce the symptoms of ADD/ADHD (attention-deficit disorder/attention deficit hyperactivity disorder). We cannot survive without nature. Green trees, green shrubs, green plants, and green spaces along with wildlife are indispensable for human survival. Photosynthesis is the biggest miracle on Earth. "No Photosynthesis Means No Respiration". No photosynthesis means no life on Earth. Green plants around us are constantly busy removing carbon dioxide,

methane, and nitrous oxide (Sundqvist et al., 2012; Timilsina et al., 2020) from the air to use in a process known as photosynthesis, via this process, trees remove pollutants and provide us with a constant supply of oxygen. Living organisms that are dependent upon oxygen came only after the great oxygenation event or oxygen catastrophe (Margulis, 1986), when photosynthetic bacteria developed capability to oxidize water and learned how to use water as an electron donor about 2.460-2.426 Ga (billion years) ago. A healthy lifestyle means a healthy nutritional program and moderate but chronic physical exercise. But one aspect is often neglected: spending time outdoors, under the canopy of trees. This is highly undervalued in modern society. Living among trees includes many benefits along with pleasure and comfort. We do not have full forests, whatever we have are just the fragmented forests on Earth and they still have many therapeutic benefits. They protect us against most clinical diseases, like cardiovascular diseases, diabetes, cancer, and particularly respiratory infections (Roviello et al., 2022; Turner-Skoff & Cavender, 2019). Physical activity builds up a strong immune system against viral diseases by activating the autonomous nervous system that releases immunoregulatory hormones (Jesus et al., 2021). Trees release negative ions (anions) that inhibit the growth of bacteria and viruses. The negative air ions (NAI) help in treating respiratory, cardiovascular, and digestive diseases (Jiang et al., 2018; Wang et al., 2020). Trees release biogenic volatile organic compounds (VOCs) which include phytoncides (Wang, 2019) (Fig 1). The practice of spending time amongst trees is known as forest bathing and started as forest therapy in many countries like China, Japan, Korea, and Europe in early 2000 (Wolf, 2019). Right now, it is time to revolutionize the whole world, to stop unnecessarily cutting down trees. Trees are the soul of the planet Earth, and the only way we will save our future is by stopping the cutting down of trees. Love for nature, wildlife, and humanity will stop future catastrophes and pandemics.

Forests:

Forests are defined as an area of land dominated by trees. There are more than 800 definitions of forests around the world with some countries using several definitions at the same time. According to the Food and Agriculture Organization of the United Nations (FAO), based upon its Global Forest Resources Assessments (FRA), a forest includes a minimum height of trees of 5 m, at least 10 % crown cover or canopy, and a minimum forest area size of 0.5 hectares. Based on this definition, there are 4 billion hectares of forest in the world, covering in all about 30 % of the world's land area (*Forest definition and extent*, 27 January 2010). According to a new global map study compiled on 429,775 ground-sourced measurements of tree density from every continent on Earth except Antarctica, we have 3.04 trillion trees, approximately 1.30 trillion in tropical and subtropical forests, 0.74 trillion in boreal regions and 0.66 in temperate regions (Crowther et al., 2015).

Forest Bathing:

The World Health Organization has described "Indigenous traditional medicine" as the sum total of knowledge and practices, whether explicable or not, used in diagnosing, preventing or eliminating physical, mental and social diseases (World Health, 2019).

Over 85-90% of the world's inhabitants use indigenous medicines for primary health care. Approximately 50,000–70,000 plant species are used in indigenous medicines (Turpin et al., 2022; Wangchuk, 2018). India and China use 20% and 19% of the local flora for treating various disorders, respectively (Wangchuk & Tobgay, 2015), and more than 25% of prescription drugs and many more synthetic drugs are derived from plants and phytochemical precursors (Rates, 2001; Turpin et al., 2022). A study published recently identified 135 species of Queensland aboriginal plants as medicinal plants, which treated 62 different diseases, with the highest number of plants used for skin sores and infections (Turpin et al., 2022).

Old Forests represent the biggest treasure on Earth which human beings have been treating as a wasteyard or menace. Old forests along with purifying air, create a microclimate and irreplicable habitat as compared to young and monoculture forests, especially for endangered species (Turpin et al., 2022). Old trees also fix nitrogen which allows for its bio-availability, as shown in forests of British Columbia, Canada (Gilhen-Baker et al., 2022). They create below-ground conditions for tree regeneration in their immediate surroundings. Old forests maintain ocean ecosystems, e.g., by providing the necessary iron for the *Cyanobacteria* survival (Gilhen-Baker et al., 2022; Krachler et al., 2019). Their unique cellular structure makes them ideal hosts for endogenous fungi, which are a rich source of phytochemicals with high therapeutic applications. One of the recently studied species of arboreal mushroom with a promising treatment for COVID-19 is Agarikon, *Fomitopsis officinalis* (Roviello et al., 2022) (Fig 1), also known as an elixir of life, grows on old trees. Agarikon has been used for thousands of years for its antiviral, antibacterial, anti-inflammatory, antituberculosis, and antitumor properties (Elkhateeb et al., 2019).

Well, even having green colored or forest pictures at home or workplace relaxes our mind, just being surrounded by forests not only makes us feel better but may help us be good. An ancient practice involving spending time around trees, also known as "Shirin Yoku" or forest bathing (Wang, 2019) has many physiological, immune, and mental health benefits (Fig10)(Antonelli et al., 2019). Trees release biogenic volatile organic compounds (VOCs) which include phytoncides (Wang, 2019). Recently in a forest bathing study on Taiwanese Sugi trees (*Cryptomeria japonica*) phytoncides, a substantial amount of limonene – a key terpenoid constituent – was found, which influences the central nervous system … improves sleep quality, reduces anxiety, and eases pain. Most of the conifer forests release d-limonene, α-cedrene, β-elemene, α-terpinene, sabinene and α-copaene, but α–pinene was the main compound in phytoncides (Wang, 2019). Along with conifers like Sugi, the balsam poplar has been shown to release oleoresins and beneficial vapors which spread around and protect the respiratory health of humans and other mammals (Beresford-Kroeger & Kroeger, 2010). A lot of plants like cedar, garlic, locust, oak, onion, pine, tea tree, many spices and many other plants give off phytoncides. These are widely used in Russian, Ukrainian, Korean, Chinese, and Japanese medicine, as well as in alternative medicine, aromatherapy and veterinary medicine (Borukh et al., 1974; "Phytoncide. ," 2022, September 6). It is important to grow these trees around the hospitals and workplaces, so folks can enjoy forest therapy

during lunchtime. Students should have their classes and important learning time in these forest areas.

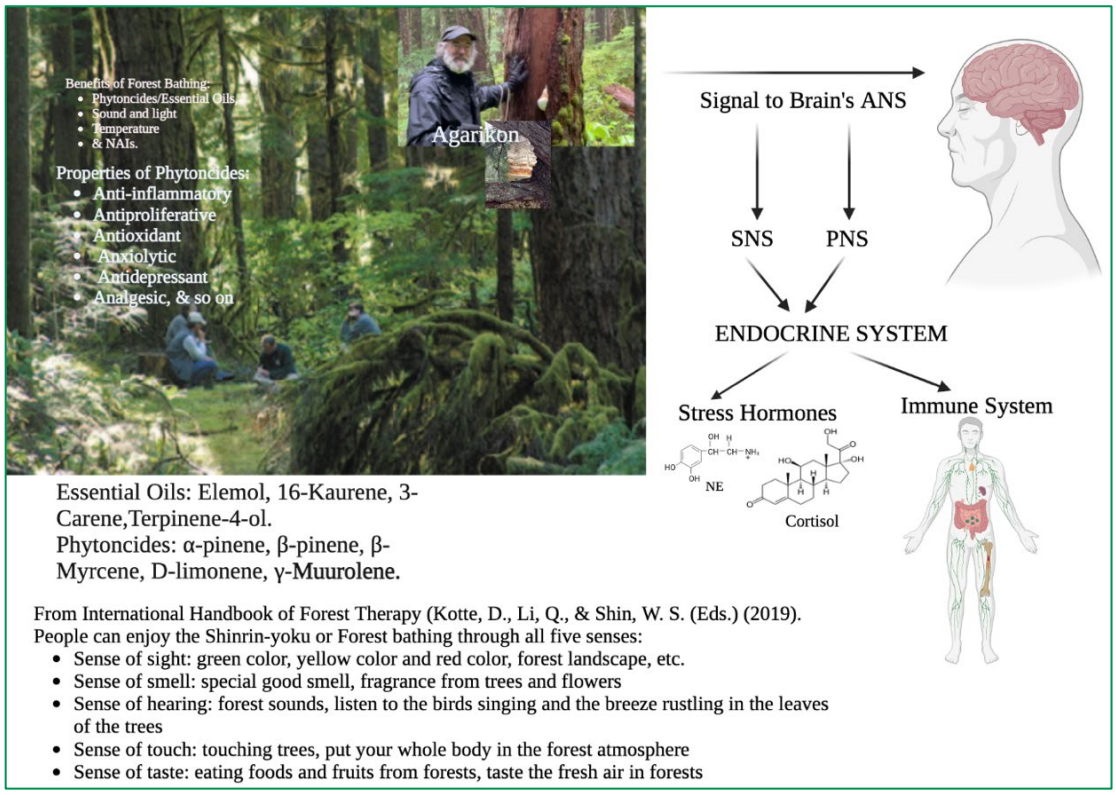


Fig 1. Showing the benefits of Forest bathing. Dr. Paul Edward Stamets, the famous mycologist and his favorite mushroom, Agarikon (Fomitopsis officinalis) (Stamets, November 13, 2009). His group has isolated and genomically sequenced 27 strains of Agarikon mushroom (Stamets, November 13, 2009). This Figure was developed from *Thangaleela et al*., 2022 (Thangaleela et al., 2022), Wang, 2019 (Wang, 2019), & *Antonelli et al.,* 2019 (Antonelli et al., 2019). This Fig. was Created with BioRender.com.

ANS=Autonomous Nervous System

SNS=Sympathetic Nervous System

PNS=Parasympathetic Nervous System

NE=Norepinephrine

The Global Carbon Cycle:

Electromagnetic energy travels in waves and spans a broad spectrum from very long radio waves to very short gamma rays, also known as an electromagnetic spectrum or EMS ("Introduction to the Electromagnetic Spectrum.," 2016). The human eye can only detect a small portion of this EMS which is known as visible light. Plants are green in color because chloroplasts contain a pigment known as chlorophyll which exists in two

forms chlorophyll a and chlorophyll b. Chlorophylls absorb light most strongly in the blue and red portion of the visible spectrum while reflecting the green color. There are three broad classes of plant pigments: porphyrins, carotenoids, and flavonoids. Chlorophylls come under the category of porphyrins. Carotenoids include carotenes (yellow or orange), lycopenes (orange or red), and xanthophylls (yellow). Flavonoids include flavones & flavanols (both yellow) and anthocyanins (red, purple, or even blue) (Helmenstine, 2022).

The global carbon cycle is driven by two main life processes: photosynthesis and respiration (Fig 2). Via the process of photosynthesis, plant chlorophylls convert carbon dioxide and water into glucose and oxygen in the presence of sunlight. There are about 100 chloroplasts in each mesophyll layer of leaves (Woodson, 2016). Photosynthesis converts ~200 billion tons of CO_2 into complex organic compounds annually and produces ~140 billion tons of oxygen in the atmosphere (Johnson, 2016). Photosynthesis happens in two main reactions at two main chlorophyll centers of photosystem I and II, also known as the antenna complexes, where accessory chlorophylls and other carotenoids like pigments transfer photonic energy by successive fluorescence event to the neighboring molecules until reach the reaction center containing chlorophyll a (GM, 2000). The light reactions take place in thylakoids and dark reactions take place inside the stroma of chloroplasts (GM, 2000). During the light reactions, water is oxidized and oxygen is released, the electrons freed from water are transferred to ATP (Adenosine triphosphate) and NADPH (Nicotinamide adenine dinucleotide phosphate). In dark reactions (Calvin cycle), the energy from ATP and NADPH is used to fix carbon dioxide, which results in the formation of sugar molecules.

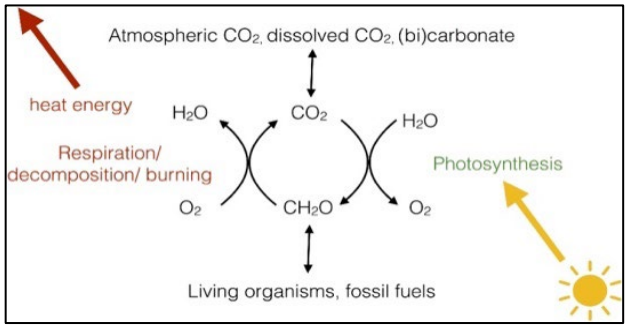


Fig 2. The Global Carbon Cycle (Johnson, 2016)

Respiration and photosynthesis are the two major driving forces of Earth's carbon cycle (Fig 2). The end products of photosynthesis are used by all of the consumers on Earth. And the end products of respiration are transformed into usable food and our essential gas oxygen (O_2) by plants. Life on Earth is based upon these two miraculous processes. A series of respiratory reactions take place in cytoplasm and mainly in mitochondria of cells while the photosynthetic reactions take place in chloroplasts of plant cells only. Both of these organelles were evolved from endosymbiotic bacteria (Archibald, 2015; Howe, 2008). At the end of their life cycle when these living organisms die, carbon in these decaying organisms becomes fossil fuels and is released back into our atmosphere once again by human.

We had an oxygen explosion, we had more than enough resources to thrive on Earth. What did we do to our natural resources? Why do we have natural catastrophes and pandemics? What have we done?

What are Climate Science and Climate Change?

What we see and feel in the atmosphere around us every day is weather, but the average temperature, humidity, the amount of rain, and wind from light to stormy gale of a region, for a particular time is known as the climate. The combined climate of our planet Earth is known as Earth's climate.

A change in this usual weather pattern in a certain place for a long period, for example, a drastic change in the amount of rain, snow, or sleet; a rise or fall in the temperature; or a sudden change in the storm frequency, pattern, category; drought, lack of rain, or desertification of a region, all are part of the climate change.

Evidence that Human causing Climate Change

Based upon the new and improved uncertainty analysis by Goddard Institute for Space Studies Surface Temperature product, the annual temperature has risen by 1.1ºC in the last century (Fig 3) (Lenssen et al., 2019). This analysis has been revised from the late 1970s Hames Hansen's studies. It includes all the spatial variations while collecting weather station data and ocean data from ships, buoys, and other sensors (Lenssen et al., 2019). In the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC), which was built upon previous reports, also published that the global surface temperature was 1.09 [0.95 to 1.20] °C in 2011–2020 above from what is seen in 1850–1900 (Hans Pörtner, 2022). This estimated increase in global surface temperature is due to further warming from 2003-2012. According to WGI (Working Group I), there is at least a greater than 50% likelihood that global warming will reach or exceed 1.5ºC in the near term (2021-2040), even if we reduce greenhouse gas emissions (Hans Pörtner, 2022). If there were no technological or policy changes to reduce emission trends from their current trajectory, then further globally-averaged warming of 2.6 to 4.8 °C (4.7 to 8.6 °F) in addition to what has already occurred would be expected during the 21st century (Fig 5) (*The Basics of Climate Change*). We need to take drastic steps to save *Homo sapiens* and our wildlife from extinction.

There could be many reasons that climate change is happening. There is so much public opinion about climate change like it could be the Earth's distance from the sun; the sun is sending out more or less energy; oceans are changing; volcanic eruptions, and perhaps anthropogenic activities. Most of the peer-reviewed journal studies and IPCC assessment reports have concluded that there is more than a 95% probability that human activities over the past 50 years have warmed up our planet (Hans Pörtner, 2022). The combustion of fossil fuels for transportation, heating, cooling, and cooking releases greenhouse gases into the atmosphere, which can change the climate on Earth.

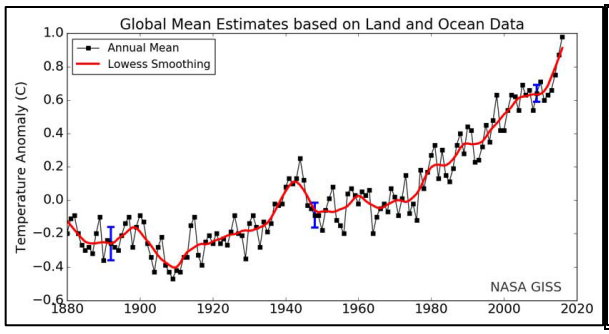


Fig 3.

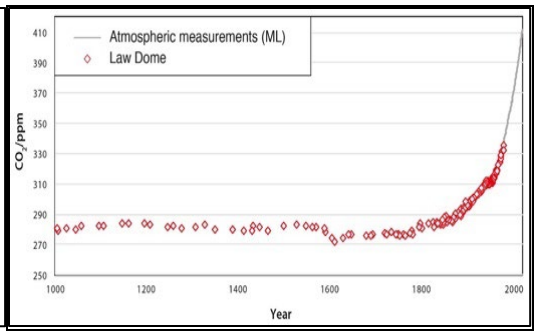


Fig 4.

Fig 3. Global Mean Estimates based on Land & Ocean Data (Lenssen et al., 2019) Source: data.giss.nasa.gov, Fig 4. Increase in CO2 ppm levels for the last 1,000 years from firn air samples of Law Dome, Antarctica(The Basics of Climate Change).

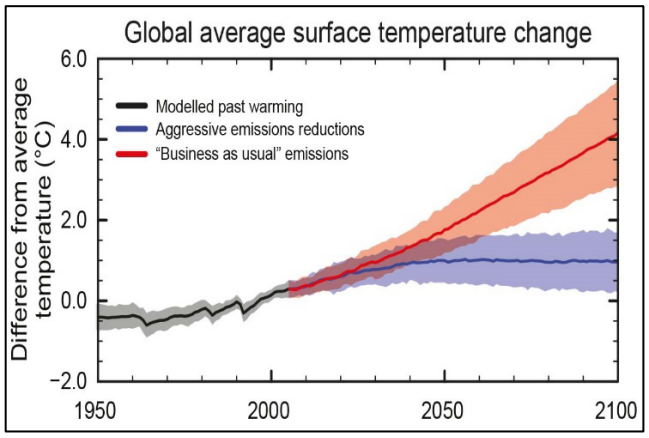


Fig 5. The global average surface temperature change expected for the 21st century depends on the total amount of greenhouse gases that we emit or control with aggressive emission reductions.

Evidence from Firn Air Samples:

There is a lot of evidence to support that human activities are the sole cause of climate change. It comes from studies of rise in Earth's temperature (Fig 3), increase in CO_2 concentration (Fig 4), and other greenhouse gases like methane, nitrous oxide (N_2O, laughing gas) (Fig 8), and water vapor levels. This data was mainly derived from firn air samples of ice core studies (Etheridge et al., 1996; Jong et al., 2022) (Fig 4). Other evidence of climate change came from an increase in ocean salinity, ocean sediments, loss of coral reefs, and catastrophic effects on biodiversity, and all are pointing at human-based unregulated fossil fuel burning and deforestation (Forster et al., 2007; Hans Pörtner, 2022).

Human activities have increased CO_2 levels above 400 ppm which were not so high for the last 400,000 years of Earth's history ("Satellite data confirm annual carbon dioxide minimum above 400 ppm [press release].", 2017; Wheeler & Watts, 2018). The answers

got clearer after we learned about the changes in atmospheric CO_2 concentration by analyzing air enclosed in polar ice sheets (Etheridge et al., 1996; Keeling, 1991a), mainly from air trapped inside the ice bubbles (Fig 4). Ice is a relatively inert storage medium for CO_2 and many other atmospheric trace gases (Etheridge et al., 1996). The ice cores from Law Dome, East Antarctica (Etheridge et al., 1996; Jong et al., 2022) have been under investigation and have provided 2,000 years of data on CO_2 levels, minerals, seasonal sea salts, annual trace ions (chloride, nitrate, sulfate, sodium, potassium, calcium, magnesium, methanesulfonic acid, and non-sea-salt sulfate), annual stable hydrogen and oxygen isotopes (Jong et al., 2022; Rubino et al., 2013). Firn is the intermediate stage between snow and glacial ice, which constitutes the upper 40 -120 m or the accumulation zone of ice sheets. Within the firn, a vast network of interconnected pores exist, which exchange air with the overlying atmosphere, and we can determine CO_2 concentrations in parts per million (ppm), these firn air samples point to a direct link of higher CO_2 levels with more use of fossil fuels after the industrial revolution (Fig 4) (Hans Pörtner, 2022).

Evidence from Argo floats:

An increase in CO2 levels causes a change in ocean surface water temperature, ocean heat content (Fig 6), and ocean salt composition, affects ocean ecosystems, causes great ice melts, extremes of weather, changes in precipitation patterns, and lack of rain, etc.(Wheeler & Watts, 2018). Oceanographers deploy Argo floats which collect information from inside the oceans. These are part of an international Argo program for studying the impact of greenhouse gases on oceans and constantly monitoring the basic parameters of oceans. In the year 2000, there were about 2,000 Argo floats, by now we have close to 4,000 active floats. An Argo float is a robotic instrument that measures temperature, pressure, and salinity. It is a cylinder of just over 1 meter long and 14 cm wide. At the top, it contains a conductivity, temperature, and depth sensor (CTD) unit (*How Argo floats work*). It measures temperature with an accuracy of 0.001 degrees C, pressure (closely related to depth) by 0.1 dbar (decibar), and calculates salinity using conductivity, temperature, and pressure within 0.001 psu (practical salinity units) (*How Argo floats work*; *What is Argo*, 2000).These Argo floats cover about the upper 2,000 m of the oceans. Each one goes through a 10-day cycle, at first, it spends most of its time drifting in deep ocean currents then it takes a series of measurements as it moves back up to the ocean surface, and finally, it communicates and transfers its data through the iridium satellites (*How Argo floats work*). These measurements have clearly shown that the rate of ocean warming for the upper 2,000 m has accelerated in the decades after 1991 from 0.55 to 0.67 Wm^2 (Watts Per Square Meter) (Fig 6). This warming has contributed to increase in rainfall intensity, rising sea levels, the destruction of coral reefs, declining ocean oxygen levels, and declines in ice sheets, glaciers, and ice caps in the polar regions (Cheng et al., 2019; Cheng et al., 2017; *What is Argo*, 2000).

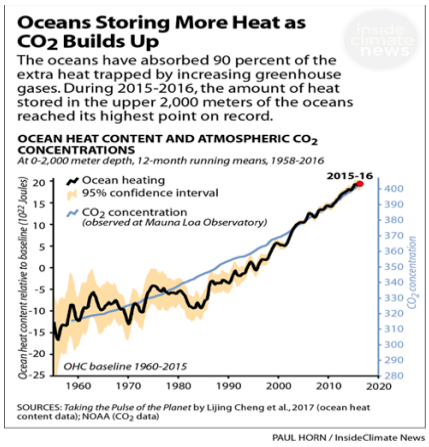


Fig 6. Increase in ocean heat content (OHC) with increasing CO2 levels (Horn, 2017)

Evidence from ROCKE-3D Models:

An increase in temperature raises evaporation, changes the partial pressure of CO_2 and its equilibrium between water and air (warm water absorbs less CO_2 as compared to cold water), increases the salinity of oceans. Recently new data on the effects of ocean salinity on climate was reported using the ROCKE-3D ocean-atmosphere general circulation model (Olson et al., 2022). These studies clearly showed the relationship between increased salinity and reduction in sea ice covers. They used three complementary model configurations: a full ocean dynamics and freezing point depression; a modified version with full ocean dynamics but no effect of freezing point depression, and lastly a slab ocean lacking ocean dynamics but including freezing point depression. All of these models suggested the increased ocean salinity from 20 to 50 g/kg of seawater resulted in an increase in the density of water, an increase in pCO2, ocean acidification, ocean warming and reduced sea ice levels (Fig 7) (Olson et al., 2022). We are on the brink of a major mass extinction and our existence is at risk since we are dependent upon the natural environment for our all-basic needs from clean water, food, and shelter, to medicine.

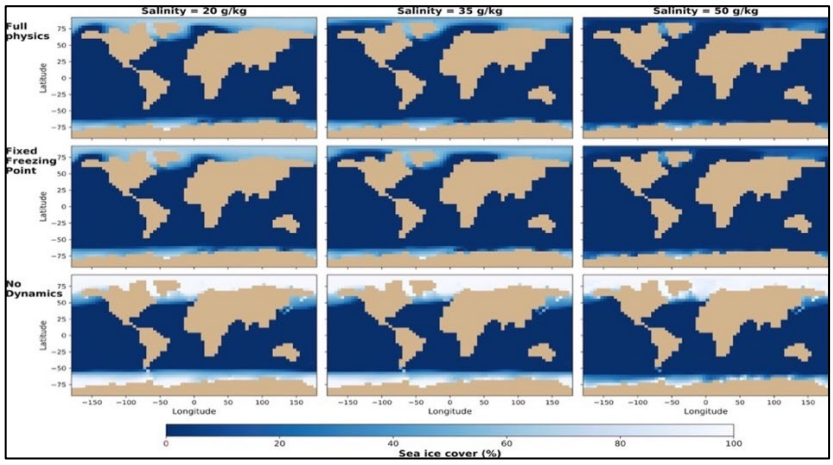


Fig 7. Increasing salinity yields lower ice cover in all scenarios, but the effects are most pronounced in model scenarios that include both dynamic and thermodynamic effects (Olson et al., 2022).

Deforestation Facts (Deforestation Facts and Statistics 2022):
Between 2015-2020, **10 million** hectares of forest were destroyed **every year**,

2,400 trees are cut down **each minute**.

By the time you finish reading this sentence, another **three hectares** of forest have been cut down.

25.8 million hectares of forest were lost in 2020, double the amount of forested land lost in 2001.

Greenhouse Effect:

We are surrounded by a layer of atmosphere, the troposphere, which reaches about 10 km or 6.2 miles above the ground. Most of the Earth's inhabitants live here, nearly all weather, clouds, precipitation, air pollution, and global warming happen in this layer. Our atmosphere contains 78.09 percent by volume nitrogen, 20.95 percent oxygen, and 0.93 percent argon. A brew of trace gases accounts for the rest of 0.03 percent (Buis, October 9, 2019). These trace gases are also known as greenhouse gases (GHGs), include carbon dioxide, sulfur dioxide, sulfur hexafluoride (SF6), methane, nitrous oxide, ozone, water vapor, halocarbons (chlorine, bromine, and fluorine) and solid or liquid particulates also known as aerosols (Wofsy, 2018). These aerosols could vary from micrometers to millimeters in size. Aerosols arise from natural sources like dust, sea salt, and volcanic emissions but also include pollutants from power plant emissions, traffic emissions, or fossil fuel emissions (Wofsy, 2018). The Montreal Protocol gases like chlorofluorocarbons (CFCs, particularly CFC-11 and CFC-12), hydrochlorofluorocarbons (HCFCs), and chlorocarbons have also contributed to GHGs although they have begun to decline (Forster et al., 2007). Concentrations of many of the fluorine-containing Kyoto Protocol gases hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF6) have increased by large factors (between 4.3 and 1.3) from 1998 to 2005 (Forster et al., 2007). The reactive gas, OH, which influences the radiative forcing values of CH4, HFCs, HCFCs, and ozone, also plays an important role in the formation of sulphate, nitrate and organic aerosol species (Forster et al., 2007). The increase in these GHGs came mainly from the start of the industrial era (about 1750) and the major contribution is by burning fossil fuels, which release carbon dioxide gas into the atmosphere. The change in climate due to human activities has exceeded the natural or solar change and volcanic emissions (Fig 8)(Forster et al., 2007).

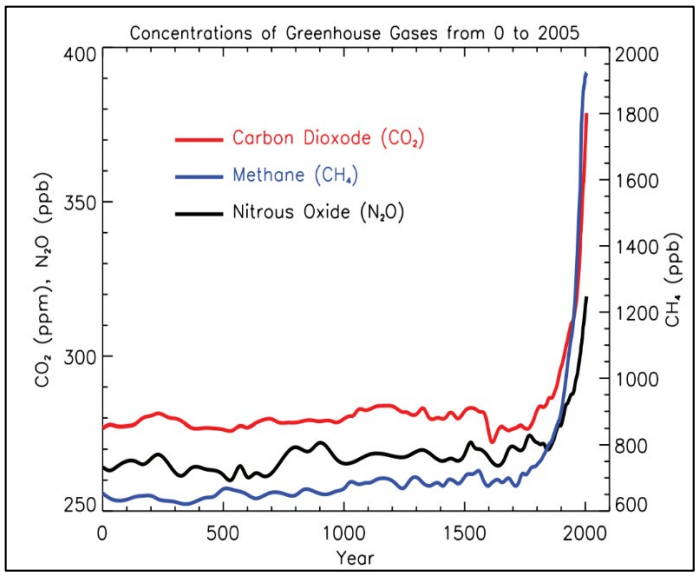


Fig 8. (Forster et al., 2007): Increase in CO_2, CH_4, and N_2O for last 2000 years, ppm= parts per million, ppb=parts per billion

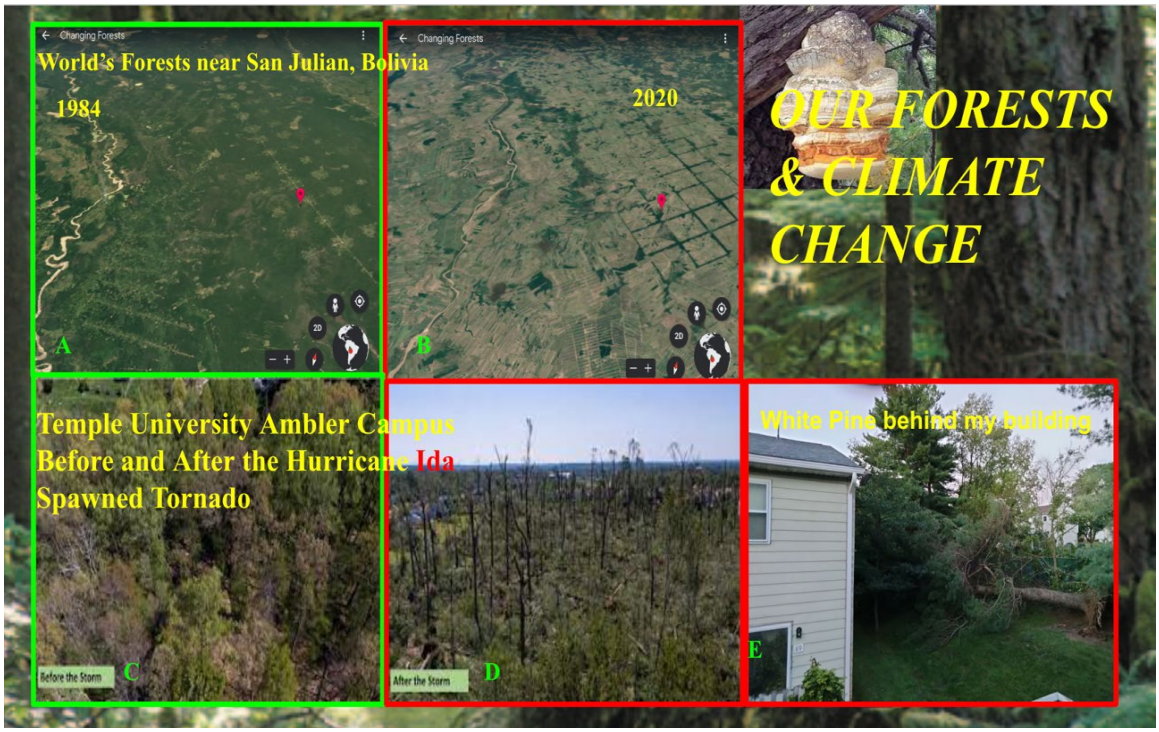


Fig 9. Deforestation and Climate Change's Catastrophic effects in our backyards. These pictures were taken from a time-lapse of Amazon forests in Google Earth; Temple University's Ambler campus before and after a tornado in October 2021, Philadelphia Inquirer.

The imbalanced levels of these trace gases cause catastrophic effects on our climate. As shown in Fig 9, these effects are already manifesting themselves on our forests and even in our backyard.

The sun's radiant energy is crucial to keep our planet warm. The sun's rays enter Earth and keep our planet nice and warm, some of this inbound energy is reflected into space as infrared radiation (thermal energy). With the rise of greenhouse gases because of human anthropogenic activities, the outgoing energy is trapped, which increases the surface temperature and controls our climate. Among these greenhouse gases, water vapor which most of us tend to overlook plays a critical role. The concentration of water vapor varies and affects global warming significantly. As the temperature of the atmosphere increases, the amount of humidity in the atmosphere also goes up, further heating our planet which changes the oceans' salinity and overall water cycle of our planet in a vicious cycle (Buis, October 9, 2019).

This imbalance of radiant energy leads to Earth's energy imbalance or EEI, which is what drives global warming. The EEI is the combination of greenhouse gases: CO_2, N_2O, CH_4, O_3, water vapor, and specifically affects our climate by altering outgoing infrared (thermal) radiation (Cheng et al., 2017; Forster et al., 2007). It is critical to start teaching about these at the school level.

Above discussion emphasizes the dire need of educating our school community and our neighbors to save our planet from climate change. I would like to invite my students to learn about the basics of plants, plant cells, the global carbon cycle, the benefits of photosynthesis and its reciprocal exchange with end products of respiration. The second component would include how trees stop climate change. It will cover the benefits of trees and effects of deforestation, field investigation of trees, Internet research, or using Google Earth on types of forests, like taiga, tropical or temperate deciduous forests, and sharing it via PowerPoints at school and community events. The second part of the unit will also include the effects of deforestation on air pollution, global warming, and the greenhouse effect. Love for trees and learning about our remnants of forests is critical for building habits of character, social-emotional learning, and life skills, like perseverance, helping others, providing equity, and contributing to the community to become better citizens. This curriculum would be a revolution to educate local communities about the importance of trees, the catastrophic effects of deforestation, and how to stop climate change at a high school level.

Objectives and Standards:

BIO.A.3.2.1 Compare the basic transformation of energy during photosynthesis and cellular respiration

LS2.B Cycle of Matter and Energy Transfer in Ecosystems - Photosynthesis and respiration provide most of the energy for life processes. Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.

PS3.D Energy in Chemical Processes and Everyday Life - The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis

BIO.B.4.2.4 Describe how ecosystems change in response to natural and human disturbances (e.g., climate changes, introduction of non-native species, pollution, fires).

How Climate Change Works: What is the cause-and-effect relationships between natural and human processes and Earth's climate?

HS-ESS2-4 Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.

Predicting Climate Change: How can we model, predict, and manage the effects of change in the Earth's climate?

MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

MS-LS2-5 Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

Teaching Strategies:

In the school district of Philadelphia (SDP), members of *Homo sapiens* are highly diverse just like our planet. SDP offers a stimulating, spellbinding, and challenging teaching environment. It is essential to be able to adapt multiple strategies from day-to-day lessons. A few examples of these strategies include enthusiasm, scaffolding through reading, writing, vocabulary, Internet searches, clear and effective instructions, think-pair-share, collaborative learning, problem solving, creativity, and innovation. Developing relationships to build long-term memories and hands-on activities are the essence of the science curriculum.

Know the Students and Develop Relationships:

At the school district of Philadelphia, good rapport with students weighs above any other teaching strategies. Due to COVID-19 and high inflation, Philadelphians have a tight budget that affects young scholars' emotional development. Every day's lesson requires balanced counseling and teaching at different levels in the same classroom. Starting class lessons by taking student vitals through the mood meter motivates them and keeps them engaged in learning. Long learning memories are well-maintained by connecting subject

matter through emotional skills. Since the COVID-19 pandemic, social-emotional learning has become an integral part of our pedagogy.

Kinesthetic and Tactile Style Learning:

Benjamin Franklin says:

"Tell me and I forget,

Teach me and I may remember,

Involve me and I learn."

Since schools are highly diversified, learning through visual, auditory, read/write and kinesthetic styles is extremely important. We all learn better by incorporating touch, movement, and feeling techniques. In science classes, adapting scientific topics into daily life examples, for example, letting students make double helix of DNA using hand gestures, pairing students to represent chromosomes, and moving to the middle or to the ends of the classroom to model plant mitosis. Let students hold hands to understand β-glycosidic bonds among glucose molecules of starch. Let students enjoy a snow jacket as a cell wall of a plant cell. Below are the highlights of this curriculum, including plant biology, Internet searches, tree-plenish event, forest awareness, school and community presentations and climate change modeling.

Classroom Activities

SECTION 1:

Photosynthesis, The Miracle of Life

Students would learn about the basics of plants, plant cells, the global carbon cycle, the benefits of photosynthesis, and its reciprocal exchange with end products of respiration.

SECTION 2:

What are Climate Science and Climate Change?

In this section, students will learn about the role of trees in climate change. Can we still restore our forests and preserve old forests to stop climate change? What can we do to stop the effects of deforestation on air pollution, global warming, and greenhouse gas emissions?

SECTION 1

Photosynthesis-The Miracle of Life

Lesson 1. Why are plants green in color?

Objectives:

- **Students would be able to (SWBAT) identify what molecules make leaves green in order to (IOT) understand the role of chloroplasts in photosynthesis.**
- **SWBAT investigate the presence of chlorophyll by a chromatographic experiment IOT learn how to separate a mixture of pigments.**
- **SWBAT explain how paper chromatography works IOT learn how one can identify different compounds from a solution.**

Leaf Chromatography(Education.com; Gross, 2012; Helmenstine, 2022): This protocol was designed from Helmenstine, 2022, Gross, 2012, & Block, 1955.

Background: Paper chromatography separates leaf pigments based on three criteria:
1. Solubility: It is defined as the maximum amount of a substance that will dissolve in a given amount of solvent at a specific temperature (Clugston, 2000). Higher the solubility of a pigment or solute, the higher the rate of movement on the chromatograph.

2. Molecular Size: Heavy pigments would stay at the bottom and light pigments would move to the top or travel the greatest distance.
3. Polarity: Cellulose is a polar molecule, so polar molecules would stick and nonpolar would move up on the paper.

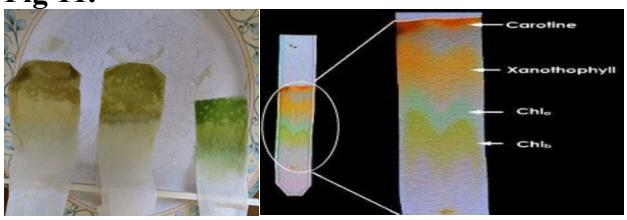
Procedure:
Collect dandelion, sorrel, spinach, parsley, lettuce, maple or oak leaves, make sure leaves are soft and not covered by trichomes.
Fig 10.

1. Wild Sorrel (*Oxalis stricta*) 2. Dandelion (*Taraxacum officinale)3. Spinach (Spinacia oleracea*) 4. Common Sorrel (*Rumex acetosa)*

1. Use the scissors to cut leaves and fill out the ¼th cup with leaf pieces.
2. Use the pestle to grind these leaves into a fine pulp containing isopropyl alcohol or 70% alcohol, or homogenize them in a food processor.
3. Cover these pulpy leaves with enough isopropyl alcohol and further stir. Leave it in isopropyl alcohol for 20 mins.
4. Cut out a strip of coffee filter paper or a white paper towel, or chromatography paper (from Amazon) about 6 inches long and 1 inch wide.
5. Adjust the strip to the pencil or a small wooden stick with a piece of tape. Make sure the bottom of the strip hangs straight.

6. Adjust the length of the filter paper strip so that its bottom just touches the green liquid homogenate in the cup.
7. Checking every couple minutes, wait for the band of solvent to migrate to the top of the filter paper. Different colored bands should become evident along the strip.
8. Study your strip, and try to identify the pigments.

Sneak Peek of Chlorophylls:
Fig 11.



Results.
The result may vary based upon the types of leaves used, the strength of alcohol, 70-100%, the type of filter used, the time of incubation of leaves in solvent and then the time of incubation of filter paper in the solvent (Education.com; Helmenstine, 2022).

Lesson 2. Floating Leaf Disc Assay

Objectives:

- **SWBAT demonstrate photosynthesis IOT learn the chemistry and the rate of photosynthesis.**
- **SWBAT conduct a simple experiment of photosynthesis IOT develop the conceptual understanding of why trees are important on Earth.**

Materials:
1.Baking soda, Sodium bicarbonate (NaHCO3) 0.2% solution containing a few drops of soap but avoid suds
2. PLASTIC syringe 10-mL (without a needle)
3. Liquid Soap
4. Spinach leaves
5. Plastic cups
6. Light source
7. Hole punch

Procedure (Williamson, September, 2019): This experiment is based upon Williamson, 2019 and Lohner, 2020.
1.Take spinach leaves, if not available, any of maple, oak, parsley, ivy, spring pokeweed, lettuce, without thick and hairy surface can be used. Now use a hole punch or a straw for single holes to make leaf discs.
2.Take a plastic syringe, remove the piston or plunger and place the leaf discs into the syringe barrel. Replace the plunger being careful not to crush the leaf discs. Now push on the plunger until only a small volume of air and leaf discs remain in the barrel, less than 10%. A 25-ml conical flask can be used in place of plastic syringe, make sure leaf

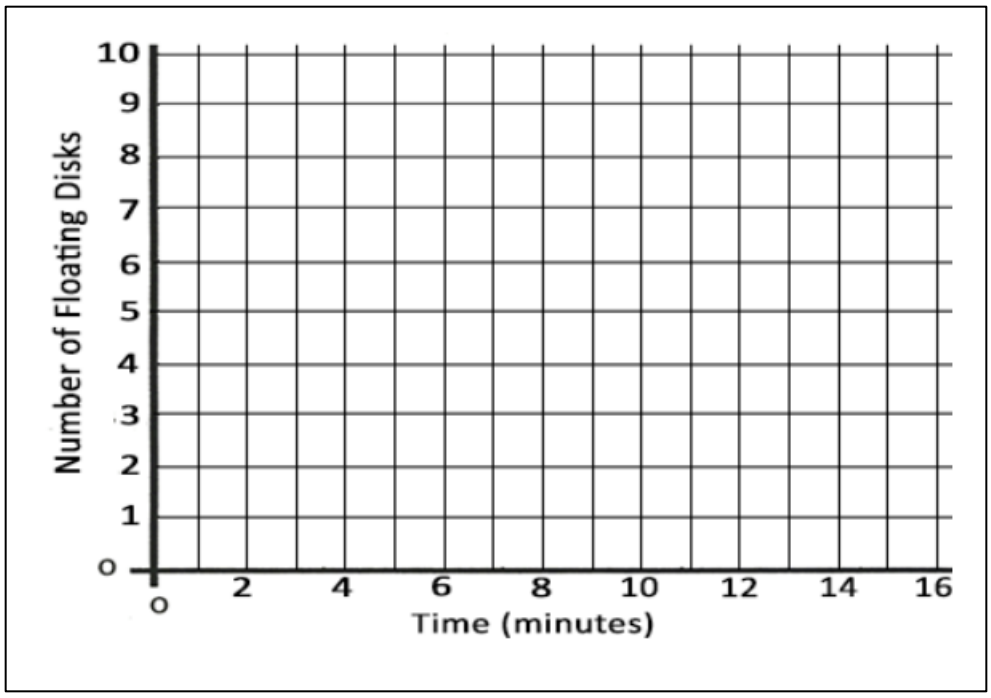
discs sink to the bottom by shaking the conical flask gently and thoroughly in 0.2% $NaHCO_3$ solution.
3. Put a small volume of sodium bicarbonate solution into the syringe. Tap the syringe to suspend the leaf disks into the solution. Holding a finger over the syringe-opening, draw back on the plunger to create a vacuum, hold it for about 10 seconds. If all of the discs don't fall into the bottom then add a few drops of soap.
4. For control do not use $NaHCO_3$, just use soap and water.
5. Transfer leaf discs into a cup containing 0.2% $NaHCO_3$ solution, place under the light until you see discs floating, count time and number of discs floating on the surface of water.
6. Control Group: Make sure as a control place leaf discs into water and same amount of soap drops as in the test group with 0.2% $NaHCO_3$.
7. Both the test group and the control should run under the same light, air and other environmental conditions until all the leaf discs are floating.

Results:

If leaves are lighter than water, then they float on its surface. If we replace stomata and spongy mesophyll which is full of air pockets by 0.2% of sodium bicarbonate (NaHCO3) solution, leaves will sink at the bottom. When these leaves in the presence of light use 0.2% $NaHCO_3$ and perform photosynthesis, they release O_2 and thus start floating again, this is an indirect measure of rate of photosynthesis. These gases and water vapor are exchanged through stomata that are present in the epidermal layer of leaves.
The time required for 50% of the leaf disks to float is represented as:
Effective Time = ET_{50} (Lohner, Oct 2020). Graph the data for the experimental group. Determine the ET_{50} for the leaf disks and determine the ET_{50} for the data. Repeated testing of this procedure has shown that the ET50, or median is a reliable and repeatable point of reference, to make comparisons between experiments. The median will generally provide the best estimate of the central tendency of the data because, on occasion, a disk fails to rise or takes a very long time to do so.

Data Table

Time (min): 1-15
# of floating discs (only NaHCO3 + soap)
# of floating discs (only H2O + soap)



Lesson 3: Relating Photosynthesis & Cellular Respiration Using Algae (Mitra et al., 2020; Norman, 1994; "Relating Photosynthesis & Cellular Respiration Using Algae,")

Objectives:

- **SWBAT explain the energy-generating process respiration IOT compare it with photosynthesis to understand the Earth's global carbon cycle.**
- **SWBAT demonstrated the necessity of light for photosynthesis.**
- **SWBAT determine the effect of photosynthesis on the carbon cycle.**

Background:

Bromothymol blue (BMB) is an indicator dye that turns yellow in the presence of acid and from green to blue at alkaline pH. So, when we breathe out carbon dioxide (CO_2) in water, it makes carbonic acid with water and lowers the pH of solution that changes BMB's color to yellow, when CO_2 is utilized in the presence of light by a plant like Spirogyra, it increases the pH, the color turns back into blue (Fig 11). This clearly demonstrates that photosynthesis is at work and it uses CO_2. The equations for respiration and photosynthesis are:

- **Cellular Respiration: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$**

  Glucose + Oxygen → Carbon dioxide + Water

- **Photosynthesis: $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$**

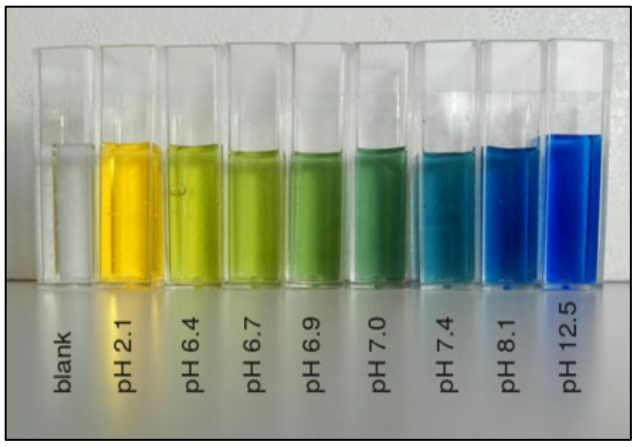


Fig 12. BMB changes color with a change in pH (*Bromothymol blue.*, 2022, October 18)

Materials:

1. Erlenmeyer flask
2. Straws and Pasteur pipettes
3. Bromothymol blue (From Amazon)
4. 4-test tubes or 10 ml conical flasks
5. Aluminum foil
6. Light source
7. Spirogyra, pond algae, or duckweed
8. Marker
9. Test-tube rack
10. 4-stoppers, or seal with paraffin film
11. Safety goggles
12. Tape

Procedure: This experiment was designed from (Mitra et al., 2020).

1. Pour 80mL of water into an Erlenmeyer flask.
2. Add 8 drops of bromothymol blue (BTB). Swirl to mix.
3. Using a straw, exhale gently into the solution until it turns yellow. You may have to take a break and again exhale, the change in color takes some time. Do not suck on the straw!
4. Pour 20mL of the yellow BTB solution into each of the 4 test tubes.
5. Place an equal amount of spirogyra into two of the test tubes. Leave the other two without any algae. Tightly stopper the tubes, you can also use paraffin film to tightly seal the tubes. Record the initial color of the solution.

6. Cover one test tube containing spirogyra and one test tube without spirogyra completely with aluminum foil.
7. Use tape and marker to label the test tubes.
8. Place them in the test tube rack under the light.
9. Check on them next day and record the color of the solution.
10. Wear safety goggles to protect your eyes.

Results:

Data Table

Tube Contents: BTB, CO_2, Spirogyra

Treatment: Dark

Initial Color:

Final Color:

Tube Contents: BTB, CO_2, Spirogyra

Treatment: Light

Initial Color:

Final Color:

Tube Contents: BTB, CO_2

Treatment: Dark

Initial Color:

Final Color:

Tube Contents: BTB, CO_2

Treatment: Light

Initial Color:

Final Color:

Students would answer the following:

1. What caused the BTB to turn yellow?
2. What would cause the BTB to return to its original blue color?

3. Why do we have two test-tubes without algae?
4. Why did we cover one test-tube containing algae with aluminum foil?
5. How can we demonstrate from this experiment that photosynthesis and respiration are interconnected?

SECTION 2

What are Climate Science and Climate Change?

Lesson 4: Is Climate Change real?

Objectives:

- **SWBAT learn what is climate change IOT understand how everybody's required to take own action to save our planet.**
- **SWBAT explain how humans and the environment are connected IOT learn how environmental imbalance can affect human health and quality of life?**

Background: Read the important articles and write a 5-page report that climate change is real and what would be your action to further stop it?
Materials:

data.giss.nasa.gov

https://insideclimatenews.org/

https://www.ipcc.ch/

https://climate.nasa.gov/global-warming-vs-climate-change/#what_is_climate_change

Procedure: Read the given articles or search more on Google Search engine with keywords "Climate change" and write a report on climate change. Student's examples are attached.
https://docs.google.com/presentation/d/18y1FtlqVEEPeXMT9wAh0KBw-Fs8gJdK_AOEEpXoYGDA/edit#slide=id.g78c8693a4c_0_8
https://docs.google.com/presentation/d/1sOdpvrFdneV-egLluzkUFZUmsrhkM0gb9wpJEyeWyjw/edit#slide=id.g78c8693a4c_0_8
https://docs.google.com/presentation/d/1FcSJUfT6eX574LCYZilbah9oPe7dUKQxoBZQnVUtNos/edit#slide=id.g78c8693a4c_0_4

Lesson 5: Google Earth Survey of forests
Objectives:

- **SWBAT take a journey through world forests IOT activate the insular cortex (taste center) without taste receptors, by the beauty of life on planet Earth.**

- **SWBAT take a survey of different types of forests and study the effects of deforestation using Google Earth.**
- **SWBAT explain how humans and the environment are connected IOT learn how environmental imbalance can affect human health and quality of life?**

Materials:
Time lapse showing forests footage
What activities in forests are beneficial for human health (Park et al., 2022)?
https://www.worldwildlife.org/industries/responsible-forestry
https://neurosciencenews.com/birds-mental-health-21749/
Causes of deforestation
https://www.nationalgeographic.com/environment/article/deforestation
Deforestation statistics
https://www.ourplanet.com/en/explore/forests/
https://forestrypedia.com/forest-types-of-world/
https://www.worldwildlife.org/places/congo-basin#:~:text=Adopt%20a%20Gorilla-,Facts,world's%20second%2Dlargest%20tropical%20forest.
Forest. (2022, October 28). In *Wikipedia*. https://en.wikipedia.org/wiki/Forest

https://www.worldwildlife.org/places/borneo-and-sumatra
https://whc.unesco.org/en/list/1167/
https://www.youtube.com/watch?v=um2Q9aUecy0&ab_channel=Netflix
https://www.youtube.com/watch?v=JkaxUblCGz0&ab_channel=Netflix

Procedure:
Discuss the important features of the tropical, temperate, and boreal forests, then categorize the following list into tropical, temperate, and boreal forests in the table:

Brazil, Bolivia, Sinharaja Forest Reserve, Sri Lanka, Indonesia, Congo, Madagascar, Philippines, Central America, North America, Ecuador and Mexico.

Use the following links for these studies:

https://ecoregions.appspot.com/

https://education.nationalgeographic.org/resource/forest-biome
https://largest.org/nature/forests/
Tropical
Temperate
Boreal

Based upon the above survey answer the following questions:

1. Why are forests important on Earth?
2. How is wildlife dependent on forests?
3. What is forest therapy? What is forest bathing?

4. Search for important medicines that come out of forests.
5. Did you have any issues understanding any words? If so, list these words here, and define them using a dictionary, or the internet.
6. How do forests benefit oceans?
7. Why it is important to save our old forests?
8. What are the important medicinal benefits of the old forest?
9. How can we enjoy *Shinrin-yoku* or forest bathing (Wolf, 2019)?
10. Why it is important to have forests around all of our workplaces and homes?

Read the following deforestation articles and answer the following questions:
Google Earth
Deforestation Gombe National Park

1. Did you have any issues understanding words in the article? If so, list these words here, and define them using a dictionary, or the internet.
2. What are the two biggest drivers of deforestation in the Amazon?
3. Why are forests on the Indonesian island of Sumatra endangered?
4. Why are forests from Alabama disappearing?
5. Who are the Surui people and how do they save Amazon rainforests?
6. How are environmentalists saving forests? Which environmental conservationist is responsible for saving Gombe National Park, Tanzania?
7. What are some of the most important discoveries of Dr. Goodall in Gombe National Park?
8. How is deforestation affecting the Chimpanzee population?
9. How are conservationists saving Chimpanzees?
10. Define deforestation in your own words.
11. Why does deforestation occur?
12. How does deforestation relate to biodiversity?

Read the history of our forests consisting of giants, their history, and restoration.
History of PA Forests:
https://www.youtube.com/watch?v=QlrXEJh5bEQ&t=551s&ab_channel=FriendsofAlleghenyWilderness
Please write a report on how PA's forest landscape has changed from the 1600s to now. What would you do to save PA's forests in the future?

Lesson 6: Greenhouse Gases Demonstration and their effects on air pollution (Exploring Climate Science)

Objectives:
- **SWBAT explain how greenhouse gases have an impact on the atmosphere.**
- **SWBAT demonstrate that CO2 speeds up the transfer of thermal energy.**

- **SWBAT explain how humans and the environment are connected IOT learn how environmental imbalance can affect human health and quality of life?**

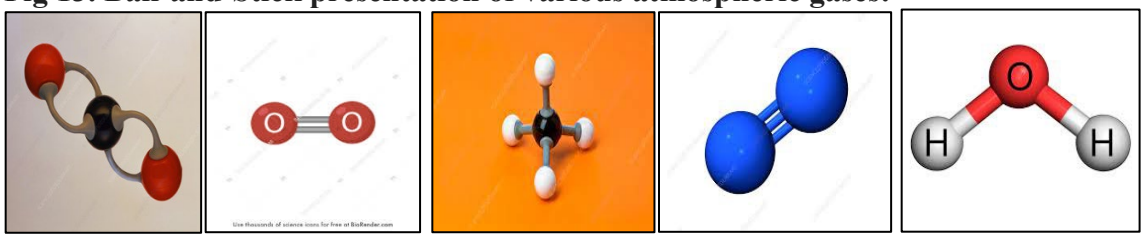
Materials:

1. Dry ice
2. Two 600 ml Beakers
3. One rubber stopper with hole
4. One vinyl tubing, 3/16" diameter
5. One clip light
6. One ruler
7. 1000-1100 (75 watt) lumen bulb
8. Two digital thermometers
9. One small piece of masking tape
10. Four Alka-Seltzer tablets
11. Safety glasses
12. Water
13. Make instruction sheets

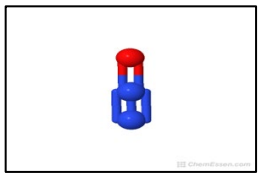
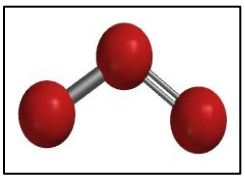
Procedure (*Exploring Climate Science*): This protocol has been modified from https://www.need.org/.
In this activity, students will be introduced to the models of chemical compounds like CO_2, O_2, CH_4, N_2, and H_2O to learn the flexibility of bonds, which trap heat or outbound energy, then students will explore the greenhouse effect in the classroom setting.

A). SWBAT explain how CO_2, CH_4, and H_2O are three of the major GHGs and have a higher impact. Demonstrate to students how there is a great deal of flexibility in the bonds of water, methane, and carbon dioxide, whereas there is very little in the bond flexibility of the other gases like N_2 or O_2 in the atmosphere.
Materials: Models of O_2, CO_2, H_2O, CH_4, N_2.

Students would make models of O_2, CO_2, H_2O, CH_4, and N_2 (Fig 12) While holding the central atom in the structures of water, carbon dioxide, and methane, apply a slight force to these atoms attached to the central atom and show how the bonds can move freely and vibrate, indicating the ability to store more energy than the bonds withing nitrogen gas or oxygen gas.
Fig 13. Ball-and-Stick presentation of various atmospheric gases:



CO2 **O2** **CH4** **N2** **H2O.**

N2O **O3**

Name of GHG: Carbon dioxide
Chemical Formula: CO2
Number of Atoms: 3
Number of Bonds: 4

Name of GHG: Nitrous oxide
Chemical Formula: N_2O
Number of Atoms: 3
Number of Bonds: 5

Name of GHG: Water (Dihydrogen monoxide)
Chemical Formula: H2O
Number of Atoms: 3
Number of Bonds: 2

Name of GHG: Ozone
Chemical Formula: O_3
Number of Atoms: 3
Number of Bonds: 3

Name of GHG: Methane
Chemical Formula: CH4
Number of Atoms: 5
Number of Bonds: 4

1. How do CO_2 levels make our planet hotter? Watch the following link. https://www.youtube.com/watch?v=OurnlNxBGX8&ab_channel=ClimateScienceDemonstrations.
2. Which things release GHGS at home? How can we reduce these?
3. How do GHGs impact our climate?

B). Demonstrate the properties of CO_2 IOT understand its role in climate change.
Materials: Dry ice, balloons, tongs, working gloves, plastic trays, beakers, safety glasses
Procedure: CO_2 stays either solid or gas. It is liquid under great pressure of above 5.1 atm (5.2 bar; 75 psi), under 31.1 °C and above -56.6 °C as shown in the phase diagram of CO_2 (Fig 14) (*Engineering ToolBox*, 2018). At the critical point of CO_2, there is no change of state when pressure or heat is added. The triple point of a substance is the temperature and pressure where three phases of that substance coexist in thermodynamic

equilibrium and shows the pressure of 5.2 bar and temp of 31.1°C for CO_2 (*Engineering ToolBox*, 2018).

1. In a beaker, pour water onto dry ice until the container is full of CO_2 bubbles and let students record the formation of the bubbles and why CO_2 is denser than air.
2. Also, students would learn about sublimation, the change of solid (dry ice) into gas.
3. Students may try blowing a balloon on top of the regular ice cube in water and dry ice in the water.
4. Light a tea-light candle. Collect a few CO_2 bubbles in a plastic cup and pour it over the tea-light candle. CO_2 is heavier than air and may asphyxiate by displacing O_2 and so extinguishes the tea-light candle because fire needs O_2. CO_2 is used in fire extinguishers.

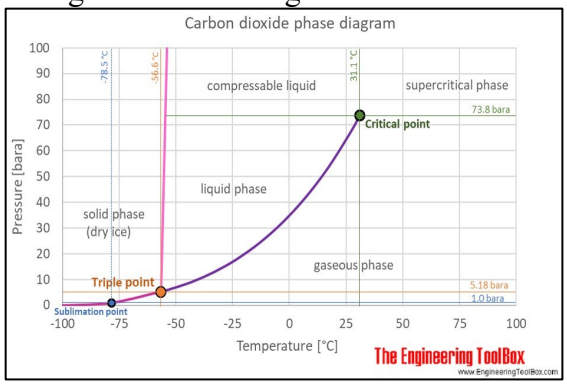


Fig 14. Phase Diagram of CO_2 (*Engineering ToolBox*, 2018)

C). Creating Earth's atmosphere in lab beakers:

Materials: Two 600 ml Beakers, four Alka-Seltzer tablets, one clip light, and a tea-light candle, two digital thermometers

Procedure: The first beaker contains the classroom's normal atmosphere. In the second beaker, we will make carbon dioxide by a chemical reaction of Alka-Seltzer in water. The active ingredients of Alka-Seltzer are aspirin, citric acid, and sodium bicarbonate ($NaHCO_3$). Upon mixing in water, the acid-base reaction transfers electrons from citric acid to base $NaHCO_3$ and forms sodium citrate, water, and carbon dioxide.

$$\mathbf{3NaHCO_3 + C_6H_8O_7 \longrightarrow Na_3C_6H_5O_7 + 3H_2O + 3CO_2}$$

Sodium Bicarbonate Citric Acid Sodium Citrate Water Carbon Dioxide

Beakers represent the air in the atmosphere and the lamp represents the sun. The first beaker contains water and the lamp. The second beaker contains the Alka-Seltzer fizzing reaction, which would show an increase in temperature after Alka-Seltzer is mixed in water. At first, the Alka-Seltzer reaction shows a little dip in temperature, but once Alka-Seltzer is completely dissolved, the temperature keeps on rising for several minutes.

After Alka-Seltzer completes its reaction, bring a tea-light candle near the beaker. Since CO_2 gas is heavier than air, it displaces O_2. Fire needs O_2 to continue burning, so once CO_2 is formed the tea-light candle is extinguished. The temperature rise in the second beaker demonstrates the global warming effect of CO_2 on the air.

Abbreviations:
SWBAT= Students would be able to

IOT=In order to

ADD/ADHD= Attention-deficit disorder/attention deficit hyperactivity disorder

ATP= Adenosine

NADPH= Nicotinamide adenine dinucleotide phosphate

OHC=Ocean Heat Content

W m^{-2}=Watts Per Square Meter

WGI= Working Group I

GHGs=greenhouse gases

CO_2= Carbon Dioxide

N_2= Nitrogen

O_3= Ozone

CH_4=Methane

N_2O= Nitrous Oxide, Laughing Gas

$NaHCO_3$=Sodium Bicarbonate

$C_6H_8O_7$ or $HOC(CH_2CO_2H)_2$ =Citric Acid

$Na_3C_6H_5O_7$ = Sodium Citrate

SF_6 =sulfur hexafluoride

CFCs=chlorofluorocarbons

HCFCs=hydrochlorofluorocarbons

Ppm= Parts Per Million

Dbar=Decibar (1dbar=10,000 Pascals)

AR=Assessment Report

F=Fahrenheit

C=Celsius

ANS=Autonomous Nervous System

SNS=Sympathetic Nervous System

PNS=Parasympathetic Nervous System

NE=Norepinephrine

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