An Introduction to Climate Change

Climate change is a complex topic. Discussed below is a general overview about some of the science behind and effects of climate change. Here are some additional resources to explore and to keep up on the most recent climate science:

- **UC Davis Science and Climate:** climatechange.ucdavis.edu
- **NASA Vital Signs of the Planet:** climate.nasa.gov
- **Nature Climate Change:** www.nature.com/nclimate
- **Smithsonian Ocean Acidification:** ocean.si.edu/ocean-life/invertebrates/ocean-acidification
- **Polar Bears International:** polarbearsinternational.org/climate-change

Introduction

Throughout history, Earth's climate has changed many times; in the last 650,000 years, there have been seven cycles of glacial advance and retreat. About 7,000 years ago, there was an abrupt end to the last ice age, which marks the beginning of the modern climate era. The majority of historical changes in climate can be attributed to very small variations in Earth's orbit that change the amount of solar energy the planet receives. Recently, scientists have begun to talk about **anthropogenic climate change**, which is climate change caused by human factors as opposed to the natural changes of Earth's climate.

In the early 1960s, scientists noticed an increase in **carbon dioxide** (CO_2) emissions that were above their expectations. Later, they noticed there was also an increase in other gases such as **methane** and **nitrous oxide**. These gases trap heat and warm the Earth, much in the same way a greenhouse traps heat from the sun, thus these gases became known as **greenhouse gases**. In fact, scientists demonstrated the heat-trapping abilities of carbon dioxide and other gases in the mid-19th century. Carbon dioxide absorbs energy from infrared radiation, which we feel as heat. Shortly after, the carbon dioxide molecule re-emits the energy it absorbed as another photon of infrared energy. This ability to absorb and re-emit infrared energy is what makes carbon dioxide an effective heat-trapping gas.

Natural sources of methane include wetlands, oceans, and the digestive processes of termites. Human sources of methane include rice production, landfills, the raising of cattle (cow burps!), and energy generation.

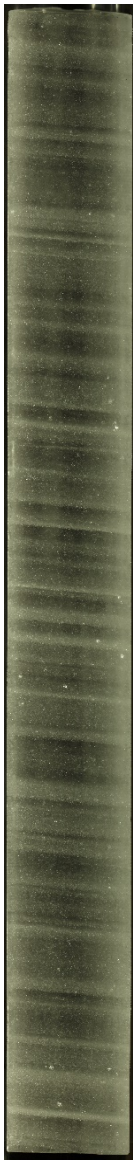
Methane

Carbon dioxide is the most commonly discussed greenhouse gas when it comes to climate change, but methane is also a key player. Since 1750, the concentration of methane in the atmosphere has risen approximately 150%. As a potent heat absorber, methane accounts for about 20% of the heating effects caused by all of the greenhouse gases. Methane exists naturally in the environment, but is also a principal component of natural gas. Burning methane in the presence of oxygen for fuel releases carbon dioxide and water vapor.

Weather vs Climate

When discussing climate change, it is important to recognize the difference between **weather** and **climate,** which is simply a matter of time. Weather is the atmospheric conditions over a short period, such as the changes we see on a day-to-day basis. Today may be partly cloudy, tomorrow may be rainy, and the following day we may expect partly cloudy skies again; these are all examples of weather patterns. Climate, on the other hand, is the atmospheric behavior over relatively long periods, generally at least 30 years. If summers feel warmer than they did 30 years ago, it is possible there has been a recent change in the climate.

Evidence for and Impacts of Climate Change



Ice Cores

Similarly to tree rings, **ice cores** (such as the one pictured on the left) provide a window into the past. The layers result from differences in the size of snow crystals deposited in the winter versus summer and resulting variations in the abundance and size of air bubbles that become trapped in the ice. Scientists use these layers to determine the age of the ice as well as past climate conditions. The gases trapped within the layers are indicators of past climate conditions.

Evidence from ice cores collected in Greenland, Antarctica, and from tropical mountain glaciers shows Earth's climate responds to changes in greenhouse gas levels. Ice cores have also revealed a positive feedback loop associated with carbon dioxide and warming temperatures. In the past, carbon dioxide levels increased after an initial temperature increase; in turn the carbon dioxide causes more warming, resulting in increased carbon dioxide levels. Overall, the ancient climate (**paleoclimate**) data reveals current warming is occurring roughly ten times faster than the average rate of post-ice age warming.

Global Temperature Rise

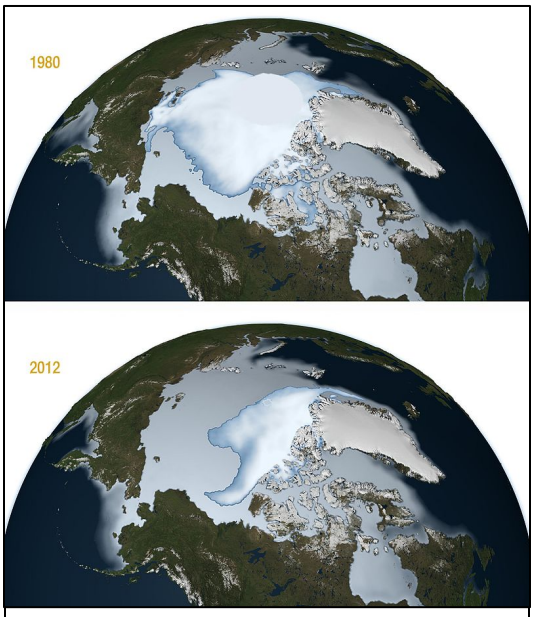
Global temperature is an average of air temperature recordings from weather stations on land and sea, and includes some satellite measurements. The amount of energy the planet receives from the sun and how much it radiates back into space determine global temperatures. The amount of energy the Earth radiates back into space depends significantly on the chemical composition of the atmosphere. Around the world, thermometer readings have steadily risen since the beginning of the Industrial Revolution (around 1760). Temperature analyses by NASA's Goddard Institute for Space Studies have shown since 1880 the global temperature has risen by approximately 0.8°C (1.4°F). Two-thirds of this warming has occurred since 1975 and temperatures continue to rise an estimate 0.15-0.2°C per decade. Rising global temperatures contribute to extreme weather events, redefine where organisms can survive, and contribute to the loss of glaciers and ice sheets.

Ice Loss

Ice loss refers to the retreat of land ice masses as well as sea ice from their historical extents. Often, this may be thought of as shrinking ice sheets and/or glacial retreat. Data from NASA's Gravity Recovery and Climate Experiment show between the years of 1993 and 2016, Greenland lost on average 281 billion tons of ice per year while Antarctica lost about 119 billion tons of ice per year during the same timeframe. Within the last decade, the rate of Antarctica's ice mass loss tripled. During the timeframe from 2003-2010, the total global ice mass lost from Greenland, Antarctica, and Earth's glaciers and ice caps was approximately 4.3 trillion tons! That's equivalent to 172 million Olympic-sized swimming pools.

Those are some big numbers! To put things in perspective, one million seconds is approximately 11.5 days. 1 billion seconds equals about 32 years! 1 trillion seconds equates to 31,710 years!

All of this ice loss has significant impacts on the climate as well as humans and animals around the world. Ice loss changes climate patterns by not keeping polar regions cool; ice reflects sun more than liquid water does and sea ice keeps air cool by separating warm ocean water from the cooler air. The loss of sea ice threatens the survival of indigenous peoples and polar bears who rely on the sea ice for their livelihood. Polar bears rely on sea ice for hunting, traveling, breeding, and occasionally denning. Loss of ice contributes to raising sea levels by directly adding land ice melt to ocean water.



Top image: sea ice extent in 1980. Bottom image: sea ice extent in 2012.

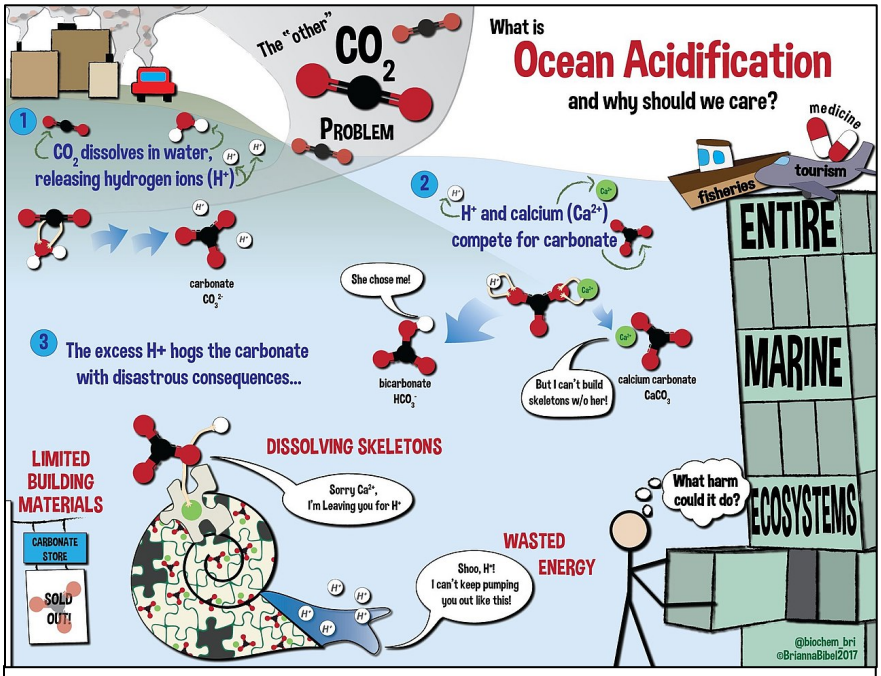
Rising Sea Level

The average level between high tide and low tide, where the surface of the sea meets a shoreline is the **sea level**. Sea level rise is simply an increase in this average level. Changes in sea level can occur naturally through expanding oceans and continental uplift or sink. However, climate change and rising global temperatures are adding two more factors: warming ocean water (causing the oceans to expand) and melting ice sheets. In the last century, the global sea level rose about 8 inches. The rate of sea level rise in the last two decades is nearly double that of the last century and accelerates slightly every year. By 2100, it is predicted sea levels will rise another 1-8 feet. Globally, the livelihood of 2 out of every 5 people is threatened directly by rising sea levels. Rising sea levels erode shorelines, contributing to coastal flooding. Water supplies become contaminated as the flow of saltwater into estuaries and groundwater increases. Sea level rising also makes coastal infrastructure more vulnerable to damage from storms. In the United States, New York City, New Orleans, and Miami are among the populations predicted to be most affected by rising sea levels.

Extreme Weather Events

Extreme weather is considered unexpected, unusual, unpredictable, severe, or unseasonal weather events occurring in an area. These events are based on a location's weather history and occur at the extremes of the historical distribution, lying in the most unusual ten percent. Since 1950, the number of **record high temperatures** has been increasing in the United States, while the number of record lows has been decreasing. The number of **heat waves** (periods of abnormally hot weather) as well as **droughts** have been increasing. In other areas, **heavy downpours** have been increasing in number, resulting in a large increase in **flooding**. Warmer air is able to hold more water vapor than cooler air and global analyses have shown the amount of water vapor available in the atmosphere has increased. This extra moisture is then available to storm systems, resulting in heavier rainfalls. Since the early 1980's, there has been an increase in most measures of Atlantic **hurricane** activity, including frequency and intensity. The recent increase has been partially linked to higher sea surface temperatures in the region of the Atlantic that hurricanes form in and move through.

The increase in frequency and intensity of **winter storms** is also linked to climate change. Remember, *climate* is about long-term trends of weather over the last 30 years. *Weather* is the changes we see on a day-to-day basis. Because of this, periodic aberrations, such as harsh winters, do not call the science of human-induced climate change into question. In 2006, Lake Erie did not freeze over for the first time in its history. This was linked to warmer temperatures and subsequently led to increased snowfalls due to increased evaporation from the lake being available for precipitation.



Excess Carbon Dioxide dissolves in ocean water, releasing Hydrogen ions, making the water more acidic. When Carbon Dioxide dissolves, it forms Carbonate ions. The excess Hydrogen ions preferentially bond to the Carbonate ions. Many sea creatures need Calcium Carbonate to form their skeletons and/or shells. However, with Hydrogen ions hogging all the Carbonate ions, Calcium Carbonate cannot form, thus these creatures cannot make their shells and/or skeletons.

Ocean Acidification

At least one-quarter of carbon dioxide released by fossil fuels dissolves into the ocean. When carbon dioxide dissolves into the ocean, it releases hydrogen ions and forms carbonate ions. The released hydrogen ions make the ocean water more acidic. Within the past 200 years, ocean water has become 30% more acidic; this increase is faster than any known change in ocean chemistry in the last 50 million years. This poses an incredibly dangerous problem for marine life, which has evolved to a relatively stable pH and they do not have the time to adapt to a decrease in pH levels. The shells and skeletons of many marine animals are dissolving due to the increase in acidity.

Coral Bleaching

1. Corals have a symbiotic relationship with microscopic algae called zooxanthellae that live in their tissues. These algae are the coral's primary food source and give them their color.
2. When the symbiotic relationship becomes stressed due to increased ocean temperature or pollution, the algae leaves the coral's tissue.
3. Without the algae, the coral loses its major source of food, turns white or very pale, and is more susceptible to disease.

Corals have a symbiotic relationship with algae, called zooxanthellae, which live in their tissues and provide energy for the corals, and give them color. In turn, the corals provide a place for the zooxanthellae to live. However, when stressed, the algae will leave the corals, causing them to become white or pale, or bleached. The leading cause of coral bleaching is rising ocean temperatures caused by climate change. Runoff and pollution also stress coral and can cause bleaching in near-shore corals. Shallow water corals are susceptible to bleaching by overexposure to sunlight, especially when temperatures are already high. Extreme low tides and exposure to air can induce bleaching in shallow corals as well.

Forests

For year, forests have been helping us by acting as a buffer against climate change. Trees and other plants take in carbon dioxide from the air and use it to synthesize carbon-containing organic compounds. As they grow, trees lock up carbon in their trunks and branches as it gets converted into the nutrients they need to grow. The Amazon Rainforest has served as the largest "carbon sink" on land, absorbing approximately one-quarter of all carbon dioxide absorbed by land each year. However, humans are adding carbon dioxide into the atmosphere faster than the trees can absorb it. Recent studies have shown the Amazon has reached its saturation point for how much extra carbon it can take up. Natural carbon dioxide emissions from plants and and outgassing from the ocean add up to approximately 776 billion tons per year, but nature absorbs about 788 billion tons per year, roughly maintaining balance. However, humans add approximately 20 billion tons of carbon dioxide per year, which skews that balance. In addition, deforestation leads to less trees that can remove carbon dioxide from the air. Overall, forests' capacity to act as a buffer to climate change is shrinking, giving further urgency to the need to reduce carbon emissions.

The weight of carbon dioxide emitted by humans **each day** is comparable to 8,000 Gulf of Mexico oil spills.

What Can You Do?

Climate change may seem like a daunting issue to overcome, but there are things you can do! Below is a list of 10 suggestions for changes you can make in your day-to-day routine. Remember though, this list is not exhaustive! There is a myriad of small changes you can make to help combat climate change (and the internet is full of ideas). Even the smallest changes can make a big difference!

1. Bring your own bottle or mug
    a. 17 million barrels of oil are used to produce plastic bottles for human consumption. That is enough oil to fuel 1 million cars for a year!
    b. Bottling water produces more than 2.5 million tons of carbon dioxide.
    c. About 80% of bottles are not recycled, meaning they end up in landfills, the ocean, or incinerated with other trash.
2. Walk or bike instead of driving
    a. The average passenger car releases 20 pounds of carbon dioxide per gallon of gas, or around 5-6 tons of carbon dioxide per year!
3. Vote
    a. Research candidates and vote for those who support climate change initiatives
4. Eat less meat
    a. Reducing your consumption of animal protein by half can cut your diet's carbon footprint by about 40%
    b. If cattle were their own nation, they would be the world's third largest emitter of greenhouse gases, after the United States and China
5. Buy locally sourced goods
    a. Minimizing the transportation of goods helps mitigate climate change
6. Reduce food waste
    a. Slightly over-ripe fruits can be made into a variety of things, such as banana bread, peach and berry cobblers, or applesauce
    b. Excess fresh herbs can be dried for use in future sauces; Fruits and veggies can be dried using a food dehydrator for a tasty treat!
    c. Many leftovers, such as fruits for smoothies, meat, broth, or veggies can be stored in the freezer and find a second use
    d. Excess leftovers? Share with a friend or take it to work and let your co-workers help you out!
7. Don't be an electricity vampire
    a. Unplug your appliances and electronics when you're not using them to avoid sucking up needless energy
8. Wash your clothes in cold/cool water
    a. Most of the energy used doing laundry goes into warming the water
9. Skip the drive-thru
    a. Sitting in line with the engine running adds more carbon to the atmosphere
10. Adjust the thermostat
    a. Set your thermostat up or down a couple degrees depending on the season. In winter, keep your thermostat around 68°F when you're not home; in summer set it around 78°F when not home. Adjust it as needed when you are home to stay warm/cool.

How to talk about Climate Change

Climate change is a difficult topic to discuss. You may feel like you don't know enough, or that it is a scary topic. Rest assured though, you do know enough! No one expects you to be a climate scientist, but knowing that 97% of scientists agree that climate change is occurring is a great place to start. Studies have shown that pointing out the scientific consensus is enough to open people up to discussion. To combat the fear associated with climate change, talk about the positive solutions to combatting climate change. Assure people they can make a difference and it isn't too late! Below are some additional tips to help you start the conversation (adapted from articles by the Nature Conservancy and by Daryl Chen for TED talks).

Meet people where *THEY* are

Understanding where the other person is coming from is one of the most important keys to having a successful conversation. Don't assume the person has the same knowledge or opinions as you; start the conversation where they would like to start. Are they interested in extreme weather events like hurricanes? Great, start there! Maybe they want to talk about shrinking sea ice or clean energy options. That's great too, run with that. Having a conversation with someone who is too wrapped up in their own ideas to listen to your needs is incredibly frustrating and does not lead to a good conversation.

Unsure of where that person is in their knowledge? Just ask! Listen patiently and with interest. Remember; don't use their answers to launch into a preconceived speech. Use their answer as the starting point for your conversation.

Facts are good, Connection is better

Many people agree that having science-based solutions matters and that facts are important. In fact, having the correct facts is essential to good decision making. However, people do not solely make decisions based on facts, but also emotion. Inconvenient facts get ignored if they do not accommodate what a person finds emotionally satisfying. To circumvent this challenge, connect climate change to the person's surroundings. You can point out how growing seasons are changing, the increased frequency of extreme weather events, or how the heat indices are rising every year. Experts agree that even climate skeptics are likely to be open about acknowledging climate change when they are able to observe its effects in events local to them. For example, in Wisconsin warmer winters mean many lakes have been freezing over later and thawing earlier, having an impact on many winter recreational activities.

Another effective strategy is to make connections between what a person values and facts regarding climate change. Then encourage environmentally friendly behaviors based on these values. If that person is health-conscious, you can point out that reducing their meat consumption gives them a better chance at living a longer life, as well as cuts down on their diet's carbon footprint. Everyone loves to save money! Encourage people to turn off lights when they leave a room or unplug electronics and appliances when not needed. Not only will that help them save money, but will reduce their energy consumption as well.

Climate Change doesn't have to be scary

People may think we've reached a point where it's too late to do anything about climate change. They may think there's no hope left. However, climate change doesn't have to be a scary topic to talk about; there is still hope left, if we act now we *can* combat climate change! Share small things everyone can do to have a positive impact, such as biking or walking instead of driving or using a reusable water bottle. Other available solutions are also highly desirable: switching to clean energy presents job opportunities and a path to cleaner air. Cleaner air and halting the dramatic warming of our climate has additional health benefits. While acknowledging the potential negative impacts caused by climate change, remember to spread a message of hope!

The goal is CONVERSATION, not confrontation

It is unlikely the person you are having a conversation with is going to immediately reverse their opinion and agree with you. No one likes to feel "wrong" or admit defeat or failure. When talking to someone about a controversial topic like climate change, it is tempting to push your opinions and knowledge until that person gives in and agrees with you, leaving you with another "win" under your belt. But remember, they're a person too with thoughts and feelings that you need to be respectful of. Be polite and listen to what they have to say. Share what worries you about climate change. For example, if you know someone effected by an extreme weather event (e.g. flooding), share that story and ask if they know anyone effected by a recent event. Overall, be patient and respectful. It may take someone multiple conversations to open up to accepting climate change; accept small steps in the right direction. Simply by having a conversation, you are making a difference by giving that person something to consider.