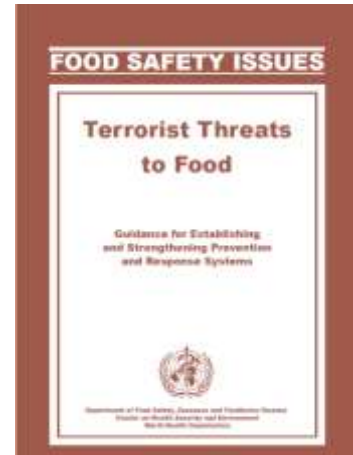


Food Security and Safety

Thank you for inviting me to talk about food security and food safety at Vontobel's Annual Roundtable Conference. After 9-11, I thought, if I were a terrorist (which I'm not), with a lot of money (which I don't) I would buy up all the farmland in the Midwest and California and either stop producing food or stop selling food. More recently, I thought that it would be not only possible but easy to find a half dozen students in each Ivy League University whose goal was to disrupt the current status quo, to gather poisons, pathogens, and radioactive isotopes from labs on campus and to use them to contaminate food in the dining halls on a given day. I think that this kind of terrorism is a real threat to food security, but before I knew it, climate change became the biggest threat to the food system. This made no sense to me.

Somehow, the public was led to believe that the climate is normally stable and that climate change has occurred since the industrial revolution; that climate change results from a single cause—the burning of fossil fuel that emits carbon dioxide and other greenhouse gases into the atmosphere; and that the increase in carbon dioxide and other greenhouse gases in the atmosphere results in global warming, food insecurity, and terrorism.

It seemed that every governmental and intergovernmental organization proclaimed that *"Climate change is highly likely to disrupt food production in many regions, increasing prices and market volatility, and heightening the risk of protests, rioting and*

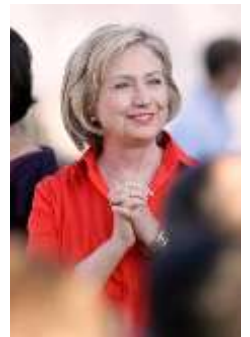


civil conflict.” The G-7 recommended that “Integration begins at home: Make climate-fragility risks a central foreign policy priority.”

One year ago, while giving the commencement address at the United States Coast Guard Academy, President Obama said, “...*the best scientists in the world know that climate change is happening...The science is indisputable. The fossil fuels we burn release carbon dioxide, which traps heat. And the levels of carbon dioxide in the atmosphere are now higher than they have been in 800,000 years. The planet is getting warmer....So I’m here today to say that climate change constitutes a serious threat to global security....Around the world, climate change increases the risk of instability and conflict....more intense droughts will exacerbate **shortages of water and food**, increase competition for resources, and create the potential for mass migrations and new tensions.*”



On the campaign trail, **Hillary Clinton** has been more nuanced about the importance of climate change on global conflict, saying, “*We have to ask ourselves: Why is this happening?*” Clinton said. *Because of terrible governance, because of corruption, because of conflict, because of climate change, there are so many reasons why people are being, in their minds, forced to leave and try to get to safety”* and **Bernie Sanders** has been less nuanced. When he was asked on *Face the Nation*: how drought connects with attacks by ISIS in the middle of Paris, he said, “...*when you have drought, when people can’t grow their **crops**, they’re going to migrate into cities. And when people migrate into cities, and they don’t have jobs, there’s going to be a lot more instability, a lot more unemployment. And people will be subject to the types of propaganda that al*



Qaeda and ISIS are using right now. So, where you have discontent, where you have instability, that's where problems arise. And, certainly, without a doubt, climate change will lead to that."

On the Republican side, **Ted Cruz** questioned the scientific nature of climate change, when he said, *"How many of y'all remember high school biology? Remember the scientific method? You start with a hypothesis and then you use evidence to try to disprove the hypothesis, to test it to see if it's true. Climate change is the perfect pseudoscientific theory because it can never, ever, ever be disproven. If it gets hotter or colder, wetter or drier — the climate has always changed since the beginning of time."* When asked about the warm winter day in Massachusetts and the UN Climate Change Conference in Paris, **John Kasich** said, *"They should have been over there talking about ISIS."* **Donald Trump** told the editorial board of the *Washington Post*, *"The biggest risk to the world, to me — I know President Obama thought it was climate change — to me the biggest risk is nuclear weapons. That's — that is climate change."*



Some things never change. According to **G. K. Chesterton** (1924), *"The whole modern world has divided itself into Conservatives and Progressives. The business of Progressives is to go on making mistakes.*

The business of the Conservatives is to prevent the mistakes from being corrected."

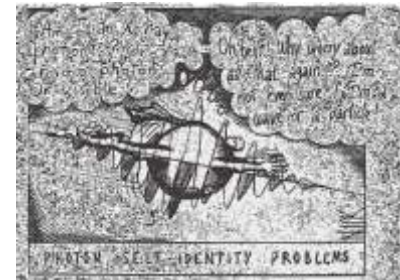


When it comes to food security, I think **Ben Franklin's** (1733) advice is still valuable: *"Distrust & caution are the parents of security."* With this in mind, I would like to present my scientific view of climate change and food security. What is science?

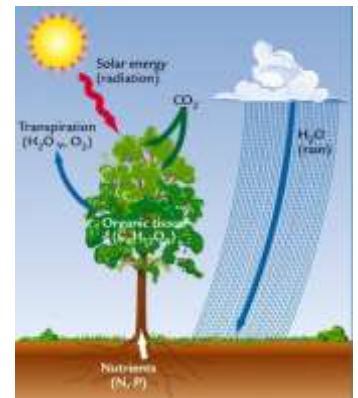
According to **Liberty Hyde Bailey**, the first Dean of the College of Agriculture and Life Sciences at Cornell University, *“To find the fact and to know the truth, --this is the purpose of the quest of science..... One never makes the quest with success unless the mind is open from the start. The quest is to find out, always to discover, never to prove a thesis or to demonstrate an assumed position. Herein does this mind differ from that of the advocate who must prove a case....., from that of the politician who must defend a party, or from that of an organization that must enforce a policy. It puts out no “feelers” to test public opinion.”*



My own research is on the nature of light, so I will begin by introducing you to the **photon**, the ultimate source of energy for all food.



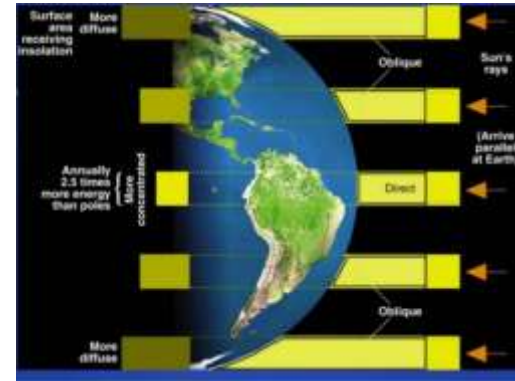
Photosynthesis is the process whereby plants transform carbon dioxide and water into carbohydrate using the energy of sunlight. Two hundred years ago, **Jan Ingenhousz** showed that photosynthesis requires sunlight, and **Jean Senebier** and **Théodore de Saussure**, two plant physiologists from Switzerland, showed that carbon dioxide and water were also necessary for photosynthesis. Today we have a great deal of knowledge regarding the role of photosynthesis in providing the food we eat.



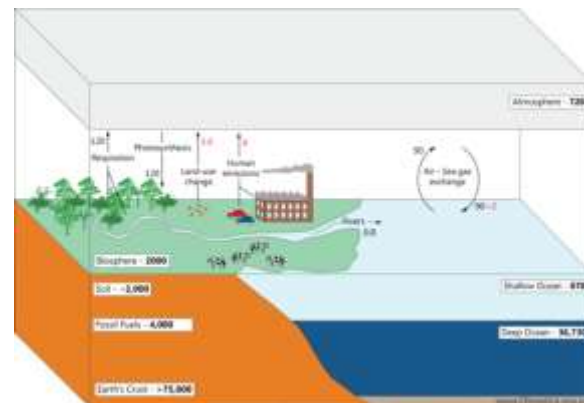
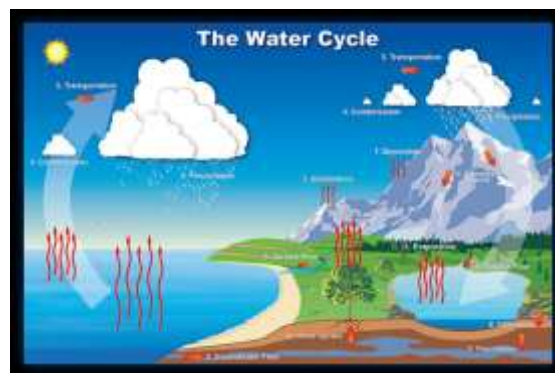
Food can be considered to be **concentrated sunshine**.

Since the earth is a sphere, the sun's rays, which carry the photons necessary for photosynthesis, strike the earth **obliquely** except at the equator. This gives rise to different climates. In fact, the word climate comes from the Greek word *clino* that means inclination, and describes the influence of the angle of the sun on climate. The difference in solar input due to the angle of the sun results in the **tropical, temperate, and polar zones**.

We can recognize the zones by the food that grows there. **Bananas** grow in the warm tropics, **corn** grows in the temperate zone, and **wheat** struggles in the cold of Siberia



Photosynthesis requires water and the distribution of plants on land depends on the **distribution of water**, which is characterized by the **water cycle**. [The sun causes water to evaporate where in a

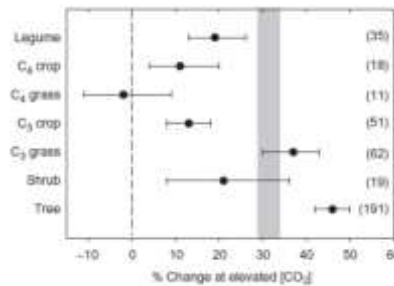


warm atmosphere it becomes water vapor and in a cool atmosphere it becomes fog. It gets transported as clouds and if it is cold enough it rains or snows]. The carbon necessary for photosynthesis comes from the carbon dioxide in the atmosphere, which is characterized by the **carbon cycle**. [Carbon in atmosphere, lithosphere,

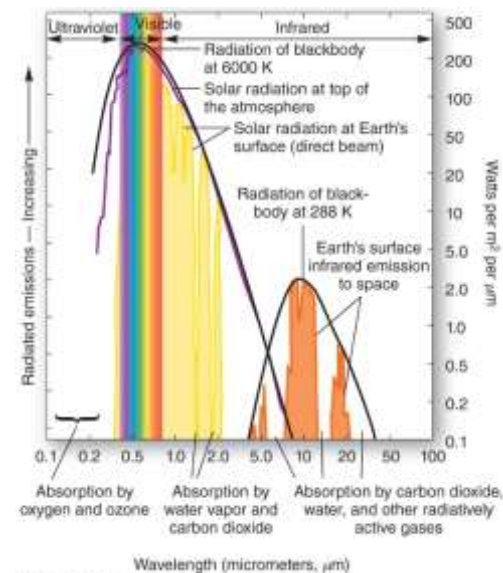
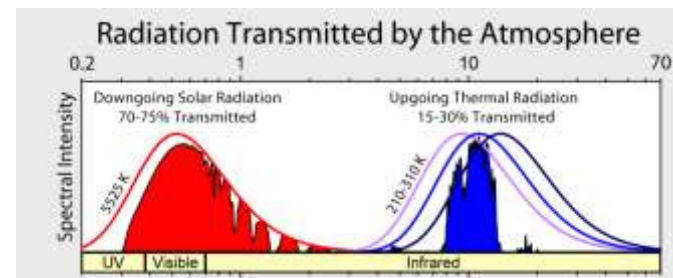
biosphere and oceans. If ocean warms, carbon dioxide is released into the environment].

The requirement for atmospheric carbon dioxide surprised the

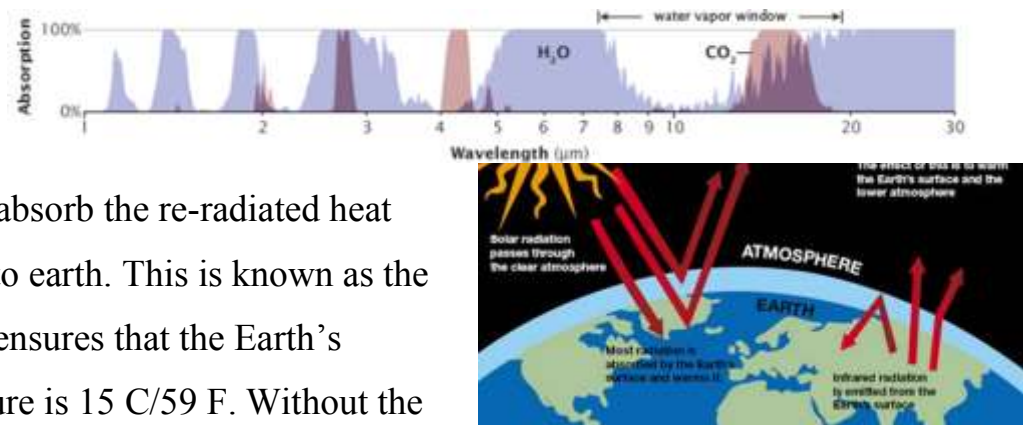
early botanists since the concentration of carbon in the atmosphere was so low compared to the concentration of carbon in the humus surrounding the plants. In fact, we now know that crop plants thrive when the carbon dioxide concentration in the atmosphere is artificially elevated in FACE experiments.



Almost all changes in the weather and climate on the surface of the earth are due to the action of the sun. Sunlight in the visible range passes through our atmosphere. The rays that are captured by the plants participate in photosynthesis. The energy of sunlight is transformed into food. Sunlight in the visible range that strikes the dark soil is absorbed by the soil and re-radiated as heat just as dark clothes absorb sunlight and re-radiate heat. The incoming sunlight has a peak wavelength of $0.5 \mu m$ and the re-radiated energy has a peak wavelength of $10 \mu m$.



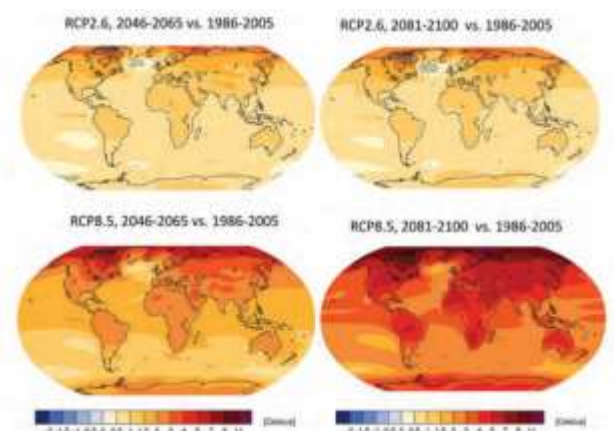
The transparent gases in the atmosphere, including carbon dioxide and water vapor, absorb the re-radiated heat rays and send them back to earth. This is known as the **greenhouse effect**. This ensures that the Earth's average surface temperature is 15 C/59 F. Without the greenhouse effect, the daytime temperature would be 117 C/242 F [hot enough to boil water] and the nighttime temperature would be -173 C/-279 F. On the average, the surface temperature would be -18 C/-0.4 F, a temperature so low that all water on Earth would freeze, and life, as we know it, would not exist.



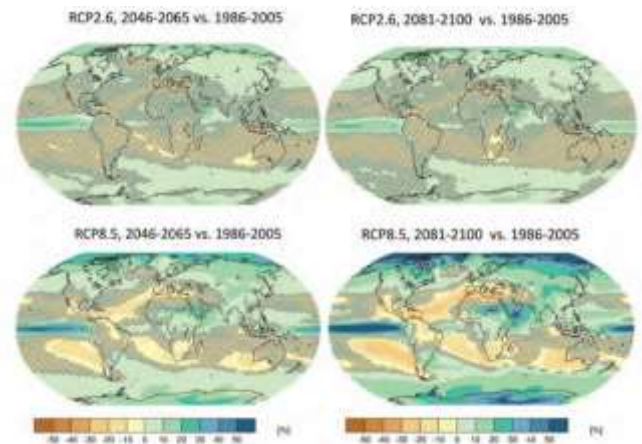
Everyone is familiar with the **hockey stick-shaped graphs** of atmospheric carbon dioxide and temperature made famous by **Al Gore** that show that since 1900, atmospheric carbon dioxide and temperature have both risen dramatically.



Climate change models based on **Representative Concentration Pathways (RCP)** such as **RCP2.6** assume that **extensive mitigation** will occur and that carbon dioxide and other GHG emitted into the atmosphere will peak between 2010-2020 and substantially decline thereafter. Models based on **RCP8.5** assume “**business as usual**” and that carbon dioxide and other GHG emitted into the atmosphere



emissions will continue to rise throughout the 21st century. Models based on RCP2.6 predict a 1 C rise in temperature by 2100, while models based on RCP8.5 predict a 4 C rise. Both models show a change in the distribution of precipitation compared with 1986-2005. According to RCP8.5, the Middle East will see more extensive drought.



Computer models are one way to predict the future, and a deep geological study of the past is another. According to **Winston Churchill** (1944) “*The longer you can look back, the farther you can look forward.*” Let’s begin our journey back at 1492.



Christopher Columbus traveled from Spain to the New World, where he found **corn**, **potatoes** and **squash**. The **Golden Age of Botany** began when he brought them back to the Old World where they could be grown in regions that were climatically similar to those where they grew in the New World. On his fourth voyage, Columbus learned of cocoa beans, which were not only used to make a hot drink, but were also used as money in the New World.



Columbus brought the cocoa beans back to the Old World which made **Swiss chocolate** possible.



In the late 1700's, the Spanish Government authorized **Alexander von Humboldt** and **Aimé Bonpland** to explore the plants and the climate in which they grew in South America. Von Humboldt paid for the trip himself.



Humboldt concluded that climates depend largely on **latitude, elevation, and proximity to water**. The fact that England is warmer than Hudson Bay Canada shows the importance of the proximity to water. Von Humboldt drew maps showing **isothermal lines**, where regions would support similar crops. The climates were relatively stable although they changed in the past as evidenced from fossil seashells found on mountains and fossils of large trees and mammals found in the arctic. He also saw that through deforestation and filling in swamps, agriculture could have a warming effect on climate.



During the Age of Botany, valuable crops such as coffee, tea and sugar were transplanted throughout the world. Many of the introductions, such as the transplantation of **breadfruit** from the South Pacific to the Carribean to be used as a food for the slaves. were dramatic.



By recalling the story of Joseph interpreting the **Pharoah's dreams** of seven fat cows and seven lean cows, and seven fat ears of grain and seven thin ones, we are reminded that there were seven good years for agriculture and seven years of drought. The climate is not always stable and thus we should always responsibly store food.



In 1783, while **Ben Franklin** was in Paris, negotiating the Treaty that would end the Revolutionary War, a volcano erupted in Iceland. Ben Franklin realized that the **volcano** caused a fog that diminished the ability of the sunshine to penetrate the atmosphere. He wrote,



“During...the summer...of the year 1783...there existed a constant fog over all Europe, and a great part of North America...the rays of the sun were indeed rendered so faint in passing through it, that when collected in the focus of a burning glass they would scarce kindle brown paper. Of course, their summer effect in heating the Earth was exceedingly diminished. Hence the surface was early frozen...The cause of this universal fog...was the vast quantity of smoke, long continuing, to issue during the summer from...Iceland, and that other volcano which arose out of the sea near that island...” The lack of sunlight resulted in famine; and misery hit France. Was the French Revolution brought on by Climate Change or by a Poor Government, who responded to the misery of the French people by saying *“Let them eat cake.”*



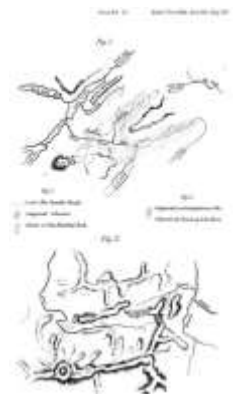
In 1815, **Mount Tambora** erupted in Indonesia. In 1816, it caused **the year without a summer** and a worldwide food shortage. It also caused the Giétro Glacier to advance, which blocked a river and formed an ice dammed lake. **Ignaz Venetz**, an engineer, tried to drain the lake; but in 1818, the ice dam failed and catastrophically flooded the village of Bagnes. In 1821, the **Swiss Natural Science Society** offered a prize for research that would address the then recent climate phenomena. Ignaz Venetz wrote the winning essay entitled *Mémoire sur les Variations de la température dans les Alpes de la Suisse*, suggesting that climate change has always occurred and **proposed that much of Europe had at one point in the past been covered by glaciers.**



Venetz concluded that the climate change is the rule. He did so by reading reports that **grape vines** no longer could be grown in places they once flourished [in the 1200s England had a thriving wine industry]; by seeing that **mountain passes** which were once open were now blocked and those that were once blocked were now open; and by seeing the ruins of **ancient buildings**, roads and forests that resulted from glacial advance or retreat [glaciers are like enormous plows that till the land]. The periodic advance and retreat of glaciers could also explain how giant boulders known as **erratics** became scattered throughout the hemisphere.



Louis Agassiz, another Swiss citizen, continued the study of glaciers. Agassiz had a great influence on American science. He became a professor at Harvard. A. D. White, the first President of Cornell, sought his advice on who to hire. Here is a statue of Agassiz at Stanford University. It fell during the earthquake of 1906. Stanford's President David Starr Jordan wrote, *"Somebody—Dr. Angell, perhaps—remarked that 'Agassiz was great in the abstract but not in the concrete.'"* Here is Agassiz' grave stone [in Mount Auburn Cemetery], a stone cut by the glacier he studied so much in Switzerland. While studying the movement of glaciers, he stayed each night at hotel with the pompous name, **Hôtel des Neuchâtelois**. It was built from the rocks broken and carried by the glacier, which are known as **glacial till**. He began each morning by bathing in a large tub of ice water, which made him feel warm the rest of the day as he tramped around the glacier. He had a cup of hot chocolate for breakfast. He ended each day with mutton and rice for dinner, a cup of coffee and a cigar. Like Venetz, he concluded from the movements of the glaciers that all of Europe was once covered by glaciers and he traveled to **Scotland** to see if this land, that presently had no glaciers, showed evidence of glaciers being there in the past. He found evidence of rocks that had been polished and scored by the retreat of glaciers, and he found moraines composed of glacial till that indicated the farthest reach of the glaciers. This proved that the earth had experienced an **Ice Age**. As an aside, Long Island is a pile of rocks [moraine] pushed by the glacier



that tilled the land. The moraine indicates the farthest reach of glaciers in the last glacial period approximately 20,000 years ago.

As a result of the invention of the steam engine by James Watt in Scotland, the mining of coal became necessary to power the industrial revolution. It was the **Golden Age of Geology**. Coal powered the Industrial Revolution and the digging of coal and the canals used to transport it gave a peak into the past history of the earth. Each layer indicated a different climate. And the plants buried in it gave an indication of the nature of a climate. Peat indicates a cool and moist environment, fossil ferns indicate a moist climate (warm or cool depending on the type of fern), while fossil oak and pine trees indicate a drier temperate environment.



By discovering alternating layers of glacial till and plant and animal remains, it became clear to **James Geike**, that there were many Ice Ages. The interglacial periods were not only

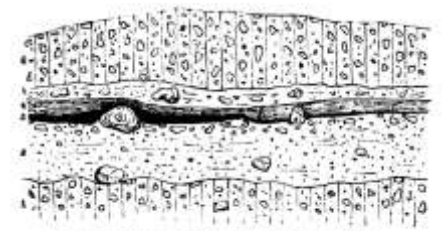
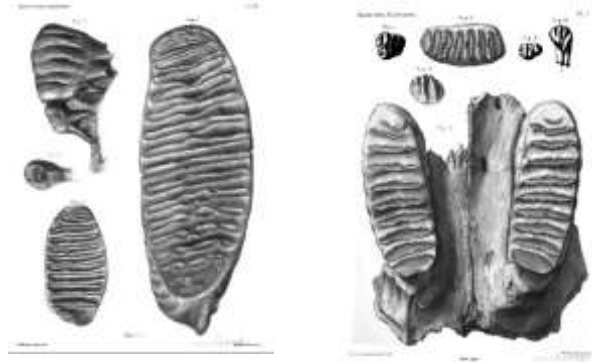


Fig. 33.—Section of glacial and interglacial deposits: Hales Quarry, near Edinburgh.

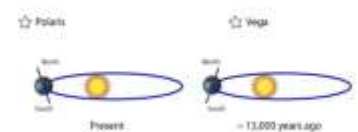
warm, but very warm, as indicated by the finding of fossil bones and teeth of **elephants** throughout Europe.



James Croll, the caretaker at Andersonian College and Museum was an autodidact who wanted to find a way to determine the actual ages of the Ice Ages. At night, Croll went to the university library and read the works of Urbain Leverrier and Joseph Lagrange who had calculated the intricacies of the Earth's orbit from **Newton's Laws of Gravitation**. Summer in the Northern Hemisphere occurs when the North Pole tilts towards the sun, which gives us the long days of summer. Winter occurs when the North Pole tilts away from the sun, which results in the short days of winter. During winter, we are actually closer to the sun (**perihelion**), and during the summer we are farther from the sun (**aphelion**), so the tilt of the earth is even more important in determining the seasonal climate than the distance of the earth from the sun. By noticing that the North Star has changed over human history, astronomers have known that the axis of the earth changes in a periodic manner. This is known as the **precession of the equinoxes** and it takes approximately **23,000 years** to complete a cycle. In addition, the shape or **eccentricity** of earth's orbit changes over a **100,000 year** cycle from circular to

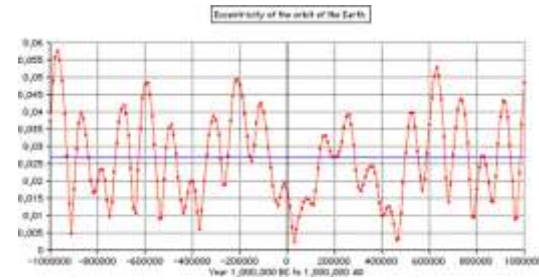


Precession

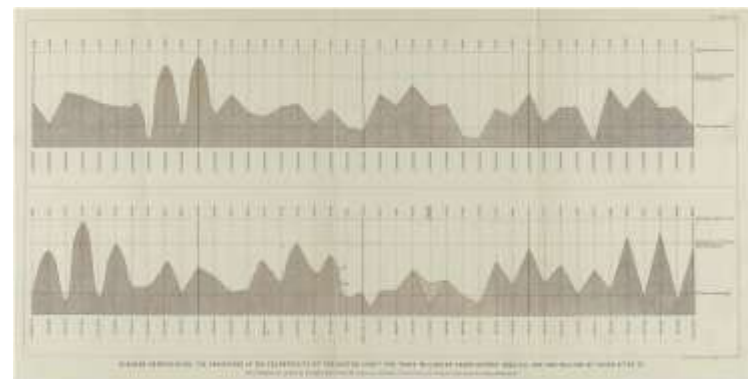


elliptical and back. When the orbit is most elliptical, the seasons are more exaggerated—the hot summers are hotter and the cold winters are colder.

When the orbit is circular, there are still seasons but the seasonal differences are reduced—the summers are less hot and the winters are less cold. Such conditions allowed the elephants to reach Great Britain. We are currently in a phase in the astronomical cycle when the eccentricity is becoming smaller, the seasonal differences become less differentiable, and the climate moderates.



James Croll put together the periods of the eccentricity and the precession of the equinoxes to retrodict the climate over the last 3 million years and to predict the climate for the next 1 million years.



Croll also realized that the temperature of the various regions of the Northern hemisphere were not controlled **directly** by the amount of sunshine, but **indirectly** by the amount of sunshine through the influence of the sun on the patterns of wind and ocean currents. If winter occurred at aphelion, the greatest distance from the sun when the eccentricity was maximal, the Northern Hemisphere would become coolest. As a result, the pole-to-equator wind, which depends on temperature differences between the pole and the equator, would



become greater. This would push the Gulf Stream south, which would make the polar regions even colder, since the Gulf Stream carries significant heat from the equator to the Pole. This is known as **positive feedback**, which is an enhancement or amplification of an effect by its own influence on the process that caused it.

Likewise, as the Northern Hemisphere got warmer, the difference in the pole-to-equator temperature would decrease and consequently the pole-to-equator wind would decrease. This would allow the return of the Gulf Stream to the north which would cause further warming. This too is positive feedback.

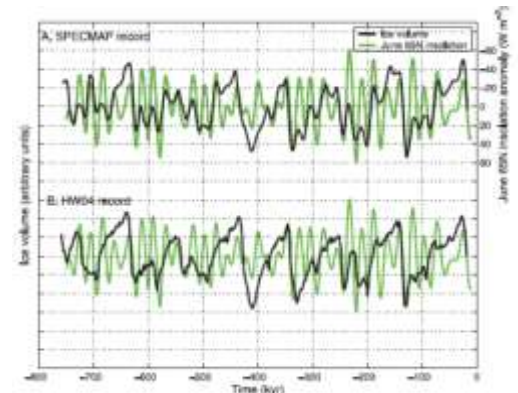
Croll realized that there were many positive feedback systems that could turn a small change in temperature into a large change in climate.

Periodic changes in the earth's orbit around the sun resulted in the exaggeration of the seasonal differences or a reduction of the seasonal differences. Through positive feedbacks, the periodicity of exaggeration and reduction of seasonality results in climate change. For example, a cooler climate causes more water vapor to condense, which causes more clouds, which reflects more sunlight from the earth. On the other hand, a warmer climate results in more evaporation, which results in more water vapor in the atmosphere and more heat scattered back to earth. Think about how the lack of water vapor in the desert results in cold nights after the sun goes down while the abundance of water vapor in Florida results in warm nights even after the sun goes down.

A cooler climate also results in more freezing precipitation which causes larger ice caps that reflect more sunlight back into space, which results in a cooler climate. On the other hand, a warmer climate results in smaller ice caps, which results in more sunlight being absorbed, which results in a warmer climate.

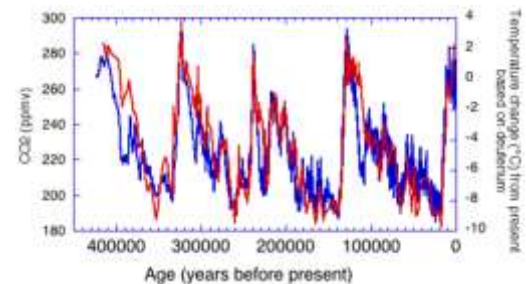
As an example of **negative feedback**, which results in a diminution or counteraction of an effect by its own influence on the cause of it, a warmer climate results in an increase in the carbon dioxide concentration in the atmosphere, which results in more photosynthesis, which results in more plant growth and more photosynthesis, which further reduces the carbon dioxide level.

Milutin Milankovich a Serbian polymath took James Croll seriously. While on his honeymoon in his native village in Austro-Hungary, World War I broke out, and he was interned because of his Serbian citizenship. He wrote, *“The heavy iron door closed behind me....I sat on my bed, looked around the room and started to take in my new social circumstances... In my hand luggage which I brought with me were my already printed or only started works on my cosmic problem; there was even some blank paper. I looked over my works, took my faithful ink pen and started to write and calculate...The small room seemed to me like an accommodation for one night during my voyage in the Universe.”* Milankovich realized that Croll’s theory would be more accurate if *the influence of the variability of the obliquity upon the insolation* was taken into account. While in prison, he added the 41,000 year periodicity in the obliquity of the earth’s axis from 21.5 to 24.5 degrees. The greater the obliquity, the greater the difference between seasons. The earth’s axis currently has a tilt of 23.5 degrees, which is declining leading to a further reduction in the difference between summer and winter. Taking into consideration the 100,000 year periodicity of the eccentricity, the 41,000 year periodicity of the obliquity, and the

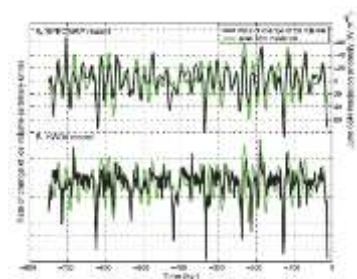


23,000 year periodicity of the precession of the equinoxes, it seems that the 100,000 year period in the eccentricity best explains the **total volume of ice**.

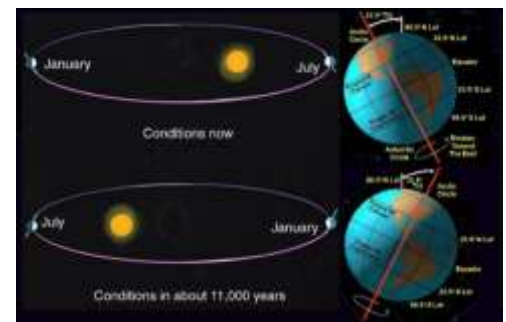
Determining the temperatures of different layers of **ice cores** using an oxygen proxy supported Milankovitch's theory of the orbital control of the Ice Ages. In fact, one can also measure the carbon dioxide concentration in the layers of the ice core and see that the carbon dioxide concentration of the atmosphere trapped in the ice is correlated with the temperature at the time the ice was formed. Note that the warm times are known as **interglacials** because the majority of the past 400,000 years, the earth has been in glacial times. Some people think that we are just coming out of the ice age.



Gerard Roe at the University of Washington, shows that while the Milankovitch Cycle is only loosely correlated with the total volume of ice, the Milankovitch Cycle, with all its periodicities, is very tightly correlated with the **change in ice volume**.



The evidence is reasonable to conclude that that the periodic change in the earth's orbit around the sun, which results in either a **moderated climate** or an **extreme climate with hot summers and cold winters**, is the historic **pacemaker for climatic change**. Changing winds, currents, and humidity amplified the effects of a change in sunlight.[note sun in top figure should be shifted left].



John Lubbock, or Lord Avebury (1912) a banker, summed up the reason why a combination of hot summers and cold winters is necessary for an ice age. *“To produce snow requires both heat and cold—the first to cause evaporation, the second to produce condensation. In fact, what we require is a greater contrast between the temperature of the tropics and of our latitudes; so that, paradoxical as it may appear, the primary cause of the Glacial Epoch may be, after all, in elevation of temperature to the tropics, causing a greater amount of evaporation in equatorial regions, and consequently a greater supply of the raw material of snow in the temperate regions during winter months.”*

As you well know, **past performance** does not guarantee future results and the cause of past climatic change may not be the cause of present and future climate change.



Another Swiss scientist, **Horace-Bénédict de Saussure** (1796), who was pictured on the 20 Franken note, and who was the father of Theodore de Saussure who showed that carbon dioxide and water are necessary for photosynthesis, built a helio-thermometer to measure the amount of incoming solar radiation or **insolation** in the Alps. He put a blackened thermometer in a box with a wall of three layers of glass to allow the sun to reach the thermometer but to prevent the outside air from cooling the



thermometer. The thermometer registered >100 F when the air was only 30 F. John Herschel repeated

Name of mountain.	Height of mountain in mètres.	Carbonic acid in the air of the mountain.
La Dôle	1267	·0461
Grand Salève-sur-Crevin .	877	·0557
Hermitage (Petit Salève) .	331	·0544
La Dôle	1267	·0491
Vasserode-sous-la-Dôle .	908	·0481
Grand Salève-sur-Grange-Tournier	945	·0413
Col de la Faucille	963	·0443
ditto	963	·0454
ditto	·0369
ditto	·0360
ditto	·0422
ditto	·0395



the experiment at the Cape of Good Hope and also cooked viands in the “solar oven” for a festive meal. De Saussure, who made all kinds of measurements using newly invented techniques, also measured the carbon dioxide concentration in the Alps. His son reported it to be approximately **400 ppmv** or 0.04 percent.

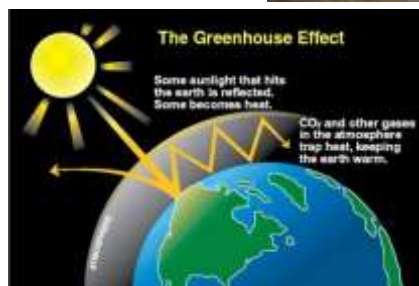
The concentration of carbon dioxide in the country of Scotland was measured by **Robert Angus Smith** (1872). He reported his results in the first book on chemical climatology. He found that the average concentration of carbon dioxide was 336 ppmv or 0.03 percent.

Carbonic Acid.			
Places between 2,000 and 3,000 feet high.		Places above 3,000 feet high.	
Name of Place.	CO ₂ in 100 pts.	Name of Place.	CO ₂ in 100 pts.
Ben Lomond	0339	Ben Muirh Dhu	0350
Ben-na-Buaid	0337	Ben Nevis	0327
Ben Voirlach	0320	Ben Ledi	0327
		Lochin-y-gair	0335
Mean	0332	Mean	0336
Mean of all the foregoing in Scotland 0336			

Where did the carbon dioxide come from? Carbon dioxide is naturally released from the earth when the warm magma of **volcanoes** come in contact with carbonates (like limestone) in the earth. In fact in 1986, so much carbon dioxide was released from **Crater Lake Nyos** in Cameroon that 1700 people and 3500 livestock suffocated. Carbon dioxide is also released from the carbonates in **oceans** when they warm, just like carbon dioxide is released from soda when the soda gets warm.



Joseph Fourier realized that the invisible atmosphere surrounding the earth, which contained carbon dioxide and water vapor, would act like the glass in de Saussure’s helio-thermometer and help retain the heat radiated by the earth.



Svante Arrhenius suggested that a 40% change in CO₂ might account for glacial advances and retreats. As a Swede, he also thought that *“By the influence of the increasing percentage of carbonic acid in the atmosphere, we may hope to enjoy ages with more equable and better climates, especially as regards the colder regions of the earth, ages when the earth will bring forth much more abundant crops than at present, for the benefit of rapidly propagating mankind.”*



Guy Callendar calculated that all the fossil fuels burned since the industrial revolution poured carbon dioxide into the atmosphere, which resulted **exactly** in the observed increase in atmospheric carbon dioxide. He suggested that the increase in carbon dioxide from 290 ppmv pre-1900 to the present might be the cause of the temperature increase that had occurred since 1900.

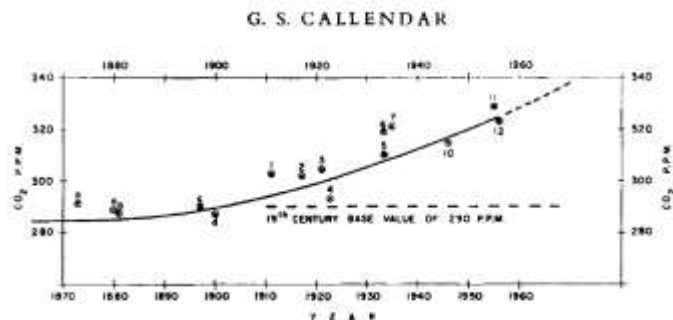
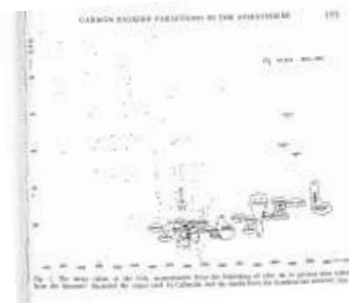
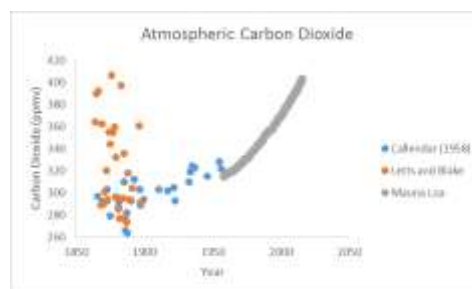


Fig. 1. Amount of CO₂ in the free air of the N. Atlantic region. 1870–1956. Full curve, amount from fossil fuel (See Appx. Table B. for numbered obs. points, and text Table 1 for the 19th century obs. points.)

But wait a minute, where were those measurements from de Saussure and Angus Smith? Two weeks ago, on a Friday I plotted the measurements (orange) of atmospheric carbon dioxide collated in a paper by Letts and Blake in 1900. Callendar had only used the lowest values for his pre-1900 estimates (blue). On the following Monday, I found a paper written in 1956 by Fonselius et al. that



recognized and confirmed the same variability. They questioned whether there was a clear trend in atmospheric carbon dioxide or was there natural variability.

Measurements taken by Neftel et al. (1985) from ice cores from **Siple Station** Antarctica showed a clear trend. And this clear trend matched up with the trend in carbon dioxide measured at Mauna Loa.

...but only if one assumes that the gas trapped in the ice is exactly 83 years younger than the ice itself. Although there are no experiments to test this assertion, they believe that it is correct because before the snow is converted to ice, it is very porous and in communication with the atmosphere. Although I do not think it is *that* porous as snow is a pretty good insulator. Who knows how long it takes the air in the ice to completely seal off from the atmosphere. One year? Two years? 83 years? Here is a presentation of the actual data, assuming that the trapped air is as old as the ice, that was given by **Zbigniew Jaworowski** to the US Senate Committee on Commerce, Science and Transportation in March 2004. [The actual data leads one to ask what are the possible sources and sinks for carbon dioxide].

By ignoring the measurements presented by de Saussure, Angus Smith, and Letts and Blake, and by assuming that the gas in a layer of the ice core is 83 years younger than the ice in that

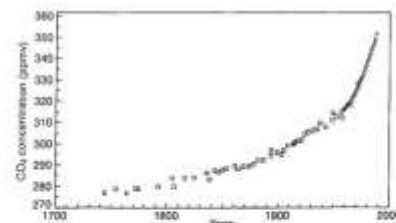
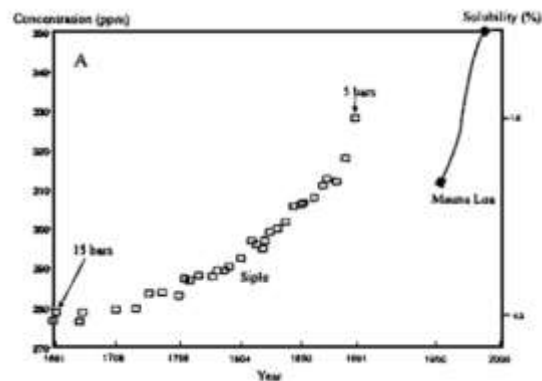
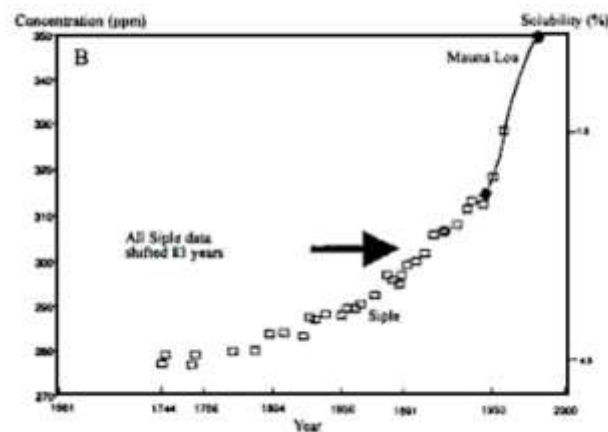
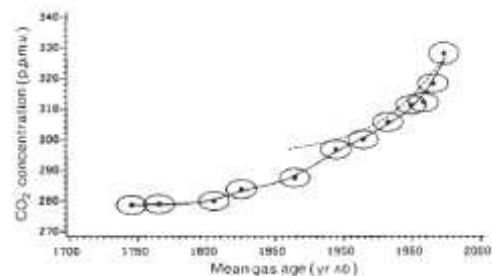
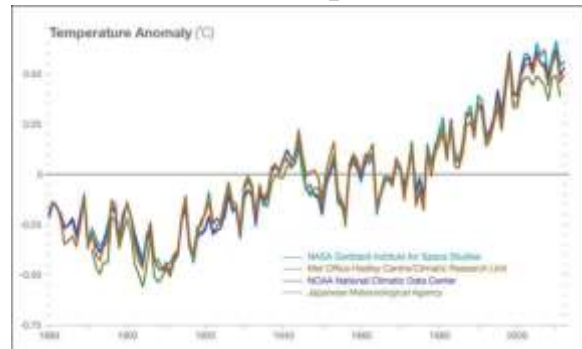


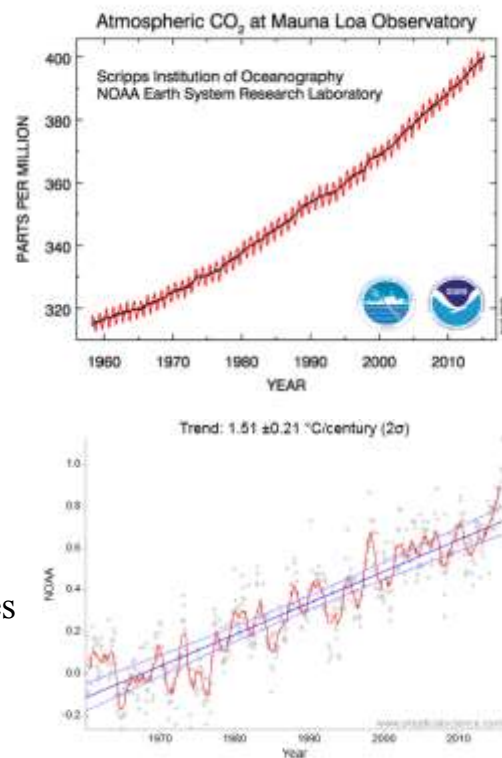
Figure 1.3: Atmospheric CO₂ increase in the past 250 years, as indicated by measurements on air trapped in ice from Siple Station, Antarctica (squares, Neftel et al., 1985a, Friedli et al., 1986) and by direct atmospheric measurements at Mauna Loa, Hawaii (triangles, Keeling et al., 1989a).

layer, we come to the famous hockey stick graph presented by the **Intergovernmental Panel on Climate Change (IPCC, 1990)**:

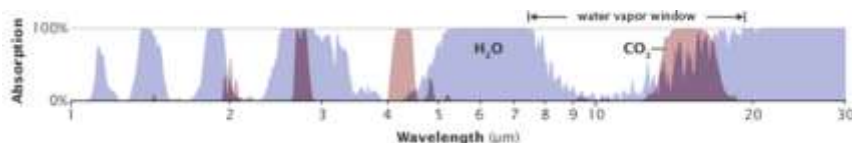
There is a **correlation between the increase in the concentration of atmospheric carbon dioxide and temperature since 1900**. The temperature **anomaly** is the difference from the average temperature between 1951 and 1980.



I want to say that it is clear that the concentration of atmospheric carbon dioxide measured in **Mauna Loa** since 1959 has increased. But I am not sure how much of that increase is due to **burning fossil fuels**, how much has been **released from the ocean** as it warms from what must be in part astronomical causes, and how much is not taken up by plants for photosynthesis as a result of **urbanization and deforestation**. It is also clear that the temperature of the earth has increased since 1959. I do not know if the relationship is one of causation and if so, does warming cause the release of carbon dioxide from the oceans or does the burning of fossil fuels result in warming.

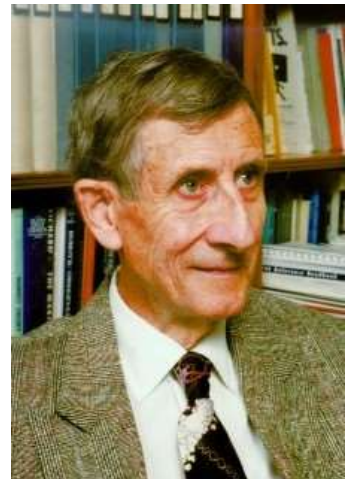


If the amount of carbon dioxide in the atmosphere was reduced to zero, the temperature on the surface of the earth would be about 0 F or 32 degrees below freezing! But how much hotter would it be by increasing the concentration of carbon dioxide in the atmosphere? Increases in



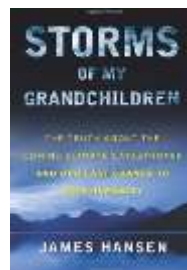
atmospheric CO₂ can only retain more heat in the spectral regions where it absorbs and where its absorption is not saturated. [Look closely at the water vapor window where carbon dioxide absorbs]. Since the earth radiates heat with a wavelength of close to 10 μm, there is only a limited possibility for an increase in carbon dioxide to absorb more heat rays and scattering those heat rays back to the earth to further warm the earth.

In science, **deduction from first principles** (which are similar to the business fundamentals) and **induction** (which means making observations and doing experiments) should advance hand-in hand. However, in the field of climate change, these two modes of scientific investigation have been marginalized by the making of computer models. In a commencement speech at the University of Michigan, **Freeman Dyson** (2005) said, *“The real world is muddy and messy and full of things that we do not yet understand. It is much easier for a scientist to sit in an air-conditioned building and run computer models than to put on winter clothes and measure what is really happening outside in the swamps and the clouds. That’s why the climate model experts end up believing their own models.”*



I have given you my point of view which emphasizes the data collected by scientists who put on heavy clothes and studied glaciers. My view

certainly differs from that of the consensus. You can read the views of the consensus in books by **James Hansen** and **Al Gore**.



In a list of talking points for physicists concerning climate change, **Spencer Weart** (2008) of the American Institute of Physics, wrote: When asked, is global warming really a problem? How do we know?



One way to answer such questions would be to invoke the authority of science. Many people are not aware that the scientific community has finally reached a consensus.

When asked, is it urgent?

How urgent is it? We don't know, and therefore it's urgent. Come again? Well, if you don't know whether your house is on fire, but there's a good chance it might be, that's urgent. Even if there's only a small chance that it will ever catch fire, you're willing to spend a significant fraction of your wealth on insurance. For climate, one mechanism that suggests we are at urgent risk can be explained to almost anyone able to grasp elementary physics. [not me]

In 2015, Spencer Weart won the American Physical Society's Abraham Pais Prize and upon accepting the prize he said to colleagues:

I have certainly not been able—any more than the IPCC in its lengthy reports—to present a convincing case, based on logic and observations, of why anyone should believe the consensus statements.

So I return to the question of *What is Science?* According to **Richard Feynman** (1969), “Science is the belief in the ignorance of experts. When someone says, ‘Science teaches such and such,’ he is using the word incorrectly. Science doesn't teach anything; experience teaches it. If they say to you, ‘Science has shown such and such,’ you might ask, ‘How does science show it? How did the scientists find out?’

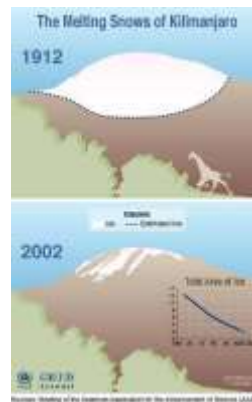


How? What? Where?’ It should not be ‘science has shown’ but ‘this experiment, this effect, has shown.’ And you have as much right as anyone else, upon hearing about the experiments--but be patient and listen to all the evidence--to judge whether a sensible conclusion has been arrived at.”

Science is argument from evidence. **Aristotle**, in **Prior Analytics**, told us that it is a false logic to prove what is not self-evident by means of itself. **Roger Bacon**, in *Opus Tertium*, told us that *“The strongest arguments prove nothing so long as the conclusions are not verified by experience. Experimental science is the queen of sciences and the goal of all speculation.”* **Francis Bacon**, in *Novum Organon*, described the **Idols of the Theater**, which are those which are due to sophistry and false learning. These idols are defended by learned groups and accepted without question by the masses. Lastly, the **Royal Society of London’s** motto is **Nullius in Verba**, Take no one’s word for it. Real science presents evidence and does not resort to making an appeal to authority.



Since von Humboldt and Bonpland were in Chimborazo, the glacier has receded and plants are moving up in elevation. I am not denying that that planet is getting warmer, I am just asking what is the cause?



I think it is advisable to combine a knowledge of the past with current research—especially research that tests and builds up the fundamental assumptions upon which climate science is founded.



We are now in an interglacial phase and I cannot tell you if anthropogenic causes are going to make the interglacial warmer and postpone the next ice age or have no effect and we will plunge into an ice age. As a Northerner, I would rather deal with food security in an interglacial climate than from under a glacier. Like Curley, I prefer a **warm steak to a cold chop**.



Archer: "You may either have your head cut off, or be burned at the stake!"
(*chuckles*)

Larry: "Cut my head off!"

Curly: "Not me, I'd rather be burned at the stake!"

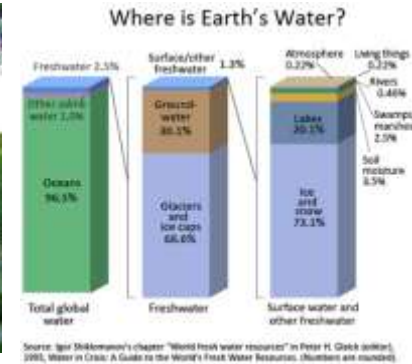
Larry: "Why?"

Curly: "A hot steak is better than a cold chop!" *BONK!*

Is the World Going to Get Warmer Due to Anthropogenic Causes?—Mitigation



Is the World Going to Get Warmer Due to Natural Causes?—Adaptation



Is the World Going to Get Warmer Due to Natural Causes?—Adaptation—Go North Young Man!



Is the World Going to Get Colder Due to Natural Causes?—Adaptation—Go South Young Man!!!



Be scientific, do not take someone's word for this. You can decide for yourself whether anthropogenic climate change is as urgent as other priorities when it comes to **food safety and security**. Study the problem, think for yourself, and trust your gut. You have a Sense of Truth!

