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In this issue: President's Message —Rebecca Reiss —A special, in depth explanation of the Greenhouse effect by Dr. Paul Braterman providing a primer on Global Warming.

PRESIDENT'S MESSAGE

The Paradox of Genetics

Dr. Rebecca Reiss

My duties as a biology professor at New Mexico Tech include teaching genetics to students in our Bachelor and Masters degree program as well as our Masters Science for Teachers program (http://www.nmt.edu). From time to time, I receive comments from students in these programs that I am too quick to dismiss intelligent design (ID). I always talk about ID in the first lecture as an example of how science is not done. If you are going to do a scientific experiment, you establish a hypothesis, a way to test your hypothesis, and an alternative (or null) hypothesis should your experiment fail. If your experiment is to prove an intelligent designer, you must accept that if it fails, you could prove there is no intelligent designer. In other words, the existence of a designer is an un-falsifiable hypothesis, and therefore not science. Other than being younger than most disciplines (about 100 years), genetics is no different from any other science in the adherence to the scientific method. Evolution is change over time and in a genetics course we focus on changes in DNA that are necessary for our existence but that can also lead to our demise from diseases like cancer. This is just one of the paradoxes of genetics that educators must convey to students, but increasingly we are faced with misconceptions planted by the ID movement. One example is the attempt to rewrite the history of the eugenics movement to discredit evolutionary principles.

Evolution is the underlying principle of biology and the evidence for it is as obvious as the evidence for gravity. It starts with your own family. Children are not clones of their parents, they are a combination of traits from their genetic ancestors. So each child is about half Mom and half Dad; it's just that simple. At the same time, it's incredibly complicated because the genetic deck is not only shuffled every generation by DNA recombination, but the genome is also tagged by the environment, a process known as epigenetics. We are just beginning to understand the role of epigenetics in human health and how our lifestyle influences future generations. Is it not obvious that no two generations are the same? The AGAG (After the Genome and Google) generation will have reproductive and medical choices like no other and they deserve to be fully educated, but the constant attacks of the ID movement create a distraction from the real issues.

Truth be told, as a geneticist, I'm offended that the ID movement gives Charles Darwin the entire responsibility for the current status of evolutionary principles; Gregor Mendel deserves some of the credit. Why is Darwin the subject of so much scorn but Mendel's contribution is generally ignored? Is this because Mendel was a Monk, or because he worked with peas? If it is the former, then it reveals their religious bias. If it is the latter, this indicates an extreme misunderstanding of genetics and its importance in evolutionary principles. It is ironic that a man of the cloth worked with the humble pea to establish the first and second principles of inheritance about the same time that Darwin was on the Beagle. IDers constantly rail against "Darwinists" so I should be safe since I'm a "Mendelist." As an important

Continued on Page 2

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Continued from Page 1

aside, there is no such thing as "Darwinism." Contributors to current evolutionary theory include Darwin, Mendel, Morgan, McClintock, Watson, Crick, Franklin, Mellow, Fire and countless others. But the ID movement specializes in rewriting history and even tries to blame Darwin for the Eugenics Movement.

My first genetics lecture always includes the history of the Eugenics Movement. I think every modern genetics text should include a chapter on eugenics since it exemplifies the consequences of widespread acceptance of pseudoscience. It was Sir Francis Galton (a cousin of Darwin) who coined the term eugenics in 1883, meaning well-bred. Eugenics was based on well-established agricultural breeding principles, including Mendel's work. Simply put, if we can breed plants and animals, why not humans? The real connection between Galton and Darwin is that both used examples from agriculture; Darwin never advocated selective breeding of humans.

Galton was reported to be a child prodigy who inherited familial wealth. His many careers included geographer, meteorologist, experimental psychologist, and mathematician. He is credited with establishing the fingerprint as a means of human identification in 1901. But it was in 1883 that Galton coined the term eugenics, which he described this way in a 1904 article:

"The aim of eugenics is to represent each class or sect by its best specimens; that done, to leave them to work out their common civilization in their own way."

But Galton only gave this idea a name. The Onieda community in upstate New York started selective breeding in the name of "Christian Perfectionism." John Humphrey Noyes founded the Onieda community in 1848, 11 years before the Origin of Species was published. The community lasted from 1848 to 1879, and in 1880 it was incorporated as the Onieda limited, now known as a manufacturer of fine cutlery. In 1888, Victoria Woodhull championed stirpiculture, the scientific propagation of the human race.

Galton also made this statement in 1904:

"I see no impossibility in eugenics becoming a religious dogma among mankind, but its details must first be worked out sedulously in the study. Overzeal leading to hasty action would do harm, by holding out expectations of a near golden age, which will certainly be falsified and cause the science to be discredited."

This is a prophetic statement, since this is exactly what happened. In 1910, the American Eugenics movement was started by Charles Davenport and Harry Laughlin at Cold Spring Harbor New York, which was then an agricultural station. By 1915, 28 states had "racial purity" laws that forbade interracial marriage, the last of which was struck down by the Supreme Court in 1967. The U.S. immigration quota system was introduced in 1924 in response to the eugenics movement. Over 60,000 people were sterilized as a result of

Continued on Page 3

pseudoscientific literature that "proved" that social ills such as poverty and criminality were a direct result of genetics. The data that supported eugenics was predominately published within publications of the Eugenics Record Office. Most of the articles in this publication did not meet even basic scientific standards, indicating a significant lapse in the peer review system. But during this time period, scientists were working to unravel the mysteries of genetics. Thomas Hunt Morgan, who won a Nobel prize for the establishment of fruit flies as a model organism in genetics, felt the conclusions of the eugenics movement were premature since the science of genetics was so young. Barbara McClintock's work with corn in the 1920s and 30s provided the first visual evidence for DNA recombination, the shuffling of the DNA deck that occurs every generation.

Despite the cold reception that the American scientific community gave eugenics, in 1933 Lauglin's sterilization model, the "law for the prevention of defective progeny" was adopted by the Nazi regime and became the justification for the sterilization of 225,000 people in the name of Aryan purity. Laughlin was awarded an honorary degree from the University of Heidelberg for his contributions to the "science of racial cleansing" in 1936. In 1939, euthanasia was established as a "final solution" and 12 million people perished. Also in 1939, the Eugenics Records Office was closed. What had been a pseudoscientific justification for prejudice became a tool for fascists who insisted they knew the way to human perfection. This is the outcome that Sir Francis Galton predicted.

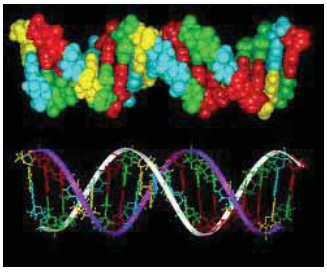
What the ID movement doesn't want you to know is that eugenics was embraced by some American religious organizations. The American Eugenics Society (AES) was supposed to be a scientific organization, yet they sponsored eugenics sermons contests. In 1916, Davenport published an article on "Eugenics as a Religion," and meetings of the AES featured talks by religious figures on this topic, including the Bishop of the Methodist Episcopal church. It's interesting to note that in 1920, the Vatican ruled eugenics as "unacceptable," but this didn't stop other religious, social, and political groups that used eugenics to justify societal changes that haunt us to the present day.

An interesting tactic used by the ID movement to confuse their followers is to link the concept of natural selection with the pseudoscience of eugenics. Natural selection is based on population genetics and gene frequencies. Alleles (variants of genes) associated with individuals who survive and breed are found in higher frequency than alleles associated with individuals who don't leave behind offspring. The leap that those who supported eugenics took without any shred of scientific evidence is that the artificial selection used in plants and animals would benefit human society. In fact, the evidence against racial purity is blatantly obvious: inbreeding. Why do most societies prohibit incest? Humans know from history that inbreeding is bad, but we are just learning why that is and why outbreeding is good.

The eugenics movement poisoned our understanding of human diversity by assigning judgment calls to human variation, whether it is controlled by genetics, the environment, or both. Many religions have rules against inbreeding because of the negative genetic consequences, but still discourage any mixing because of a false idea that outbreeding somehow "dilutes" the human stock. It is outbreeding that makes a species stronger since having a diverse population provides natural selection more variation upon which to act. The eugenics movement was based on a misunderstanding of genetics that was used to justify prejudice.

The eugenics movement represents the misapplication of the science of genetics in which sectors of the scientific and religious community were responsible. The major lesson is the science requires testable hypotheses that are based on sound evidence, not prejudice or hidden agendas. The bioethical questions now being raised by advances in genetics, reproductive medicine, and aging research require informed discussion by all members of society. Without such informed discussion, a new eugenics era will result, with only those who can afford assisted reproduction and other expensive medical techniques able to live and reproduce.

Dr. Reiss is the new President of CESE serving for the 2010/2011 term. She is an Associate Professor at New Mexico Tech, which specializes in technology and science teaching and research. It has often been a consistent top 10 contender in various rankings as one of the best technical schools in the nation. Dr. Reiss specializes in genetics.



THE SUN, THE EARTH, THE GREENHOUSE

All things glow. The coldest emptiness of outer space glows in the microwave region, corresponding to a temperature of 2.725° C above absolute zero, the pale shadow of the light in which the universe was bathed when first it was cold enough to make atoms. The bar of an old-fashioned radiant electric fire glows red, and the surface of the Sun (I will explain what I mean by "surface" later) glows yellow-white hot. The surface of the Earth glows in the infrared with an average temperature of around 15° C. But if you look at the emission spectrum of the Sun[1], you will find relatively dark lines on it, corresponding to the electronic absorption spectra of elements in the Sun's outer atmosphere, and if you look at the emission spectrum of the Earth, you will find relatively dark bands, corresponding to the absorption spectra of the greenhouse gases.

The Sun

The Sun's core, which extends from the centre for about a quarter of the total radius, has a temperature of 13.6 million° K and a density up to 150 times that of water. Here it is that hydrogen is converted to helium, the energy released being radiated out in the form of gamma rays. The rest of the Sun, up to its visible surface, is a plasma consisting of cations (mainly protons, since hydrogen is the most abundant element present) and electrons moving independently of each other. Every few millimetres, this plasma absorbs the energy streaming outwards from the core, and re-emits it time and time again. Since each layer is a little bit less hot than the one beneath it, the energy is passed on in the form of electromagnetic radiation of slightly longer wavelength, until finally it reaches what we see as the surface. Unlike Earth, the "surface" does not mark a sudden discontinuity but is the level at which the temperature is low enough for atoms to be able to hold on to their outer electrons. It is simply the layer where the plasma gives way to predominantly non-ionized gas. A plasma can absorb (and re-emit) light of any frequency, but an uncharged gas can only do this if the frequency corresponds to a change between definite energy levels[2]. So above the surface, the Sun's atmosphere becomes transparent at almost all wavelengths, and what we see is the surface itself, glowing yellow-white hot at 6000° C. Actually, the density of matter in this region of the Sun is so low ($10^{13} – 10^{14}$ particles)/cm^3, compared with around 2.4 x 10^{25} particles/cm^3 in the Earth's lower atmosphere) that light emitted even from a depth of some hundreds of kilometres is able to escape, and instead of thinking of a single surface, we should think of a layer, the photosphere.

"We can never know anything of their chemical or mineralogical structure". So said the philosopher Auguste Comte in the 1830s, speaking of the stars. He was wrong, and the investigations that would prove this were already well under way. In 1672, Newton had shone a beam of sunlight through a glass prism, breaking it down into a spectrum with all the colours of the rainbow. Wollaston in England in 1802 and later Fraunhofer in Germany in 1814 repeated this work using the high-quality glass prisms that were becoming available, and noticed the existence of dark lines in that spectrum, still known, somewhat unfairly, as "Fraunhofer lines". Over the next decades, various scientists observed that metals and indeed elements in general when sparked or intensely heated gave out light at specific frequencies, something that could be used for analysis of materials, and that these frequencies matched the frequencies of the Fraunhofer lines.

By the 1850s, it was realized that this gave a way of doing exactly what Comte had called impossible. The presence of a particular set of lines was evidence for the corresponding element, and this was as true for the outer atmosphere of the Sun as it was for a mineral specimen here on Earth. Even more so if anything; the existence of the element helium was inferred from a dark line in the Sun's spectrum some 14 years before its first terrestrial detection, in lava from Mount Vesuvius.

We would have to wait until the 20th century for Planck and Einstein to discover the relationship between frequency and energy, and for Bohr to explain the lines in terms of discrete atomic energy levels, but this had no effect on their diagnostic significance.

In present-day terminology, the Sun's photosphere generates a continuous thermal emission spectrum. It glows because it's hot, and the spectrum is continuous because the plasma (and the hydride ions) can absorb and emit at any energy. Superimposed on this, we see the line absorption spectra of elements in the solar atmosphere, and these match the line emission spectra we can obtain in the laboratory.

I have referred to "line absorption spectra". It would be more accurate to speak of lines of less intense emission. Light of the frequency that matches a particular element is absorbed and re-emitted many times in its passage through the Sun's atmosphere, and its final intensity corresponds, crudely, to the temperature of the region from which the light is finally admitted to space. This is lower than the temperature of the photosphere, corresponding to less intense emission[3]. The distinction between absorption and less intense emission will turn out to be extremely important when we discuss the greenhouse effect on Earth.

One no doubt trivial effect of the existence of the dark lines is that the photosphere is slightly hotter than it would have been without them. The reasoning is very simple. Ignoring short-term fluctuations, and very long-term trends, the total amount of energy reaching the photosphere must be equal to the amount that leaves it. But the dark lines correspond to energy that has been prevented from leaving, so the photosphere must adopt a slightly higher temperature, to compensate for less efficient emission at the frequencies of these lines.

The Earth

We turn now to the situation on Earth.

Nearly all incoming light from the Sun passes straight through the Earth's atmosphere. An important exception is light in the far ultraviolet, which is absorbed by the ozone layer and, incidentally, heats the stratosphere in the process, but we can ignore this for our purposes. This light hits the surface of the Earth, where around 70% is absorbed, while 30% is directly reflected back into space (the Earth is therefore said to have an albedo of around 0.3).

So the earth is warmed, and glows with the appropriate thermal radiation. Since the Earth's average temperature is around 15° C, or 288 degrees above absolute zero, as opposed to 6000° C for the Sun, the Earth glows in the infrared rather than in the visible. On average, the amount of energy reaching the Earth's surface must equal the amount of energy finally leaving it, and this balance, apart from a small contribution through geothermal heat from the energy of radioactive decay, is what determines the Earth's surface temperature. If there is not a balance, then in the short term the Earth either gets hotter (more energy stays than leaves) or colder (more energy leaves than stays), until a new steady state temperature is reached.

The Greenhouse

The atmosphere is transparent to visible light, but not to specific regions of the infrared, where some gases, the greenhouse gases, absorb, converting infrared light energy into molecular vibrational energy. Oxygen, nitrogen, and argon are transparent throughout the infrared, but carbon dioxide, methane, and water absorb (and, when energized, re-emit) specific frequencies of infrared light. Very importantly, while the atoms in the Sun's atmosphere absorb and re-emit sharp lines, the greenhouse gases absorb and re-emit over a range, giving band spectra, because of additional effects connected with molecular rotation.

To understand what happens next, we need to consider the structure of the Earth's atmosphere. The greater the altitude, the lower the pressure, because the pressure at any height is due to the weight of the air above it. New Mexicans will need no reminding of this, and of the need to modify recipes, for example, to compensate for the resulting lower boiling point of water. Nor will anyone who has taken the Sandia Chairlift need reminding that higher altitude leads to lower temperature. There are two apparently quite different ways of looking at this, but they come to the same thing. We can say that molecules simply lose kinetic energy, and therefore temperature, as they rise against gravity. Or we can think of air rising, expanding because of the lower pressure, and cooling because it is doing work on its surroundings (the opposite of the effect that makes the pump heat up when pressurizing a tire). So temperature decreases with height, through what is known as the troposphere, for a distance of between roughly 4 1/2 miles at the poles or 10 miles at the equator. Above this height (the tropopause) we enter the stratosphere, where temperature begins to increase with height because of the absorption of ultraviolet by the ozone layer, and above that because of further effects that are not important to this discussion.

Now consider what happens to the infrared radiation leaving the Earth's surface. At frequencies where the atmosphere is transparent, it will stream straight out into space. At frequencies where greenhouse gases absorb, that much energy will be captured, usually quite close to the surface, and is among the processes heating the lower atmosphere. But greenhouse gas molecules emit as well as absorb, so some of the absorbed energy will be deflected downwards, and some reradiated upwards, where the process will repeat itself. Ultimately, some of this energy will reach a level where it can escape into outer space. So instead of being emitted from the Earth's surface, light of that particular frequency will be from its escape level. Since this is at a lower temperature, the amount escaping is less than it would have been if the greenhouse gases had not been present, and the surface must be warmer to compensate. The result is that for a steady state to be established, the Earth's temperature must be some 33° C higher than would otherwise have been the case. To put it slightly differently, in addition to being warmed directly by sunlight with visible light, part of which is converted to infrared after absorption and reradiated outward, the surface is also warmed by the infrared light re-emitted downwards by greenhouse gases, much as an actual greenhouse is warmed by infrared light reflected downwards by the window materials. None of this, by the way, is contentious.

Now consider what happens if

Continued on Page 6

Continued from Page 5

there is an increase in the concentration of a greenhouse gas. The chance of one of its infrared photons being absorbed will be greater at any level, and the average level from which final escape occurs will be correspondingly higher. With the exception of some small regions where the escape layer is already at or very near to the tropopause, this means that the escaping emission will be coming from a layer where the temperature is that much lower, the total amount of energy escaping from the Earth will be reduced, and the surface of the Earth will adopt a higher temperature to restore the balance.

There has of course been a dramatic increase in the amount of carbon dioxide in the atmosphere over the past century and a half, related to the use of fossil fuels (and to a smaller extent to the use of limestone in cement manufacture), so that it now stands at about 40% higher than in preindustrial times. There has also been an increase in the amount of other greenhouse gases, such as methane and nitrous oxide, mainly as the result of more intensive agriculture, and the use of synthetic nitrogenous fertilizers. Most of this increase has taken place in the past 50 years, during which there has been a relentless upwards tendency in temperature. This is global warming. To be more specific, if we accept the findings of the vast majority of climatologists, there is a direct causal relationship between increased greenhouse gases resulting from human activity, and the increase in temperature. This is anthropogenic global warming.

Three complicating factors deserve special mention. Firstly, water vapor, which is the most important of all greenhouse gases. This is an amplifying factor; if the Earth's temperature rises for any reason whatsoever, the atmosphere will hold more water vapor, enhancing the greenhouse effect, and tending to produce a yet further increase. The matter is further complicated by cloud formation, which can enhance or reduce the greenhouse effect depending on exactly where the clouds form. Like greenhouse gases, they can absorb and re-emit infrared, enhancing the effect, but they also increase the Earth's albedo by reflecting light back into space before it arrives at the surface. The overall effect of clouds is the most uncertain aspect of greenhouse science, and there is even a small but vocal group of climatologists who claim that clouds will provide negative feedback, mitigating the effects of anthropogenic global warming, but this is very much a minority point of view, and it seems more likely[4] that clouds will make things worse. Secondly, there is global dimming, as a result of industrial pollution. This was a large enough effect to override and indeed reverse the general warming trend for some 20 years in the middle of the last century. The passage of clean air acts removed the worst of this, whereupon, as already predicted at the time, temperatures resumed their upward movement. Finally, there is soot, not a gas but also a product of human activity, and of wildfires made more common by that activity. Soot is black and snow is white, so soot traps far more light energy than snow, causing serious melting in the Himalayas and Tibet.

Fire, Flood, and Famine?

As I write, drought in Russia has sent grain prices soaring, while Moscow, experiencing record heat, is shrouded in smoke from burning forests and smouldering dried out peat bogs. 2010 has given us the hottest 10 months on record, monsoons fed by unusually high evaporation from the warming oceans, and devastating floods in Pakistan and China. Isn't this the result of global warming?

There is only one honest answer. Maybe. We were warned that such events would happen with increased frequency, and indeed they have. But attributing any specific event to so general a cause is going beyond the evidence. Like loaded dice, global warming changes the odds, but individual outcomes remain unpredictable.

There is a multi-million dollar publicity machine dedicated to creating the impression, in the minds of the public, that the science is not completely settled and that, therefore, no political action is necessary. Not surprisingly, the machine is funded by those with most to lose, and its conclusions are embraced by those most opposed to political action of any kind.

Such reasoning is seductive but specious. There is indeed uncertainty, regarding just how serious global warming will be under various scenarios, but this uncertainty is a reason for more circumspection, not less. It is because of uncertainties that we insure our houses, and maintain our armies. It is because of their interest in evaluating uncertainties that insurance companies have been among those most attentive to climate change research, which they started funding in the 1970s. If things may be rather less bad than we predict, they may also be a great deal worse. In the words of Margaret Thatcher, "[T]he need for more research should not be an excuse for delaying much needed action now. There is already a clear case for precautionary action at an international level." This is one of the few occasions when I found myself in complete agreement with the Iron Lady. What she said was right then, and it is right now. She was speaking, by the way, in 1990[5].

End notes:

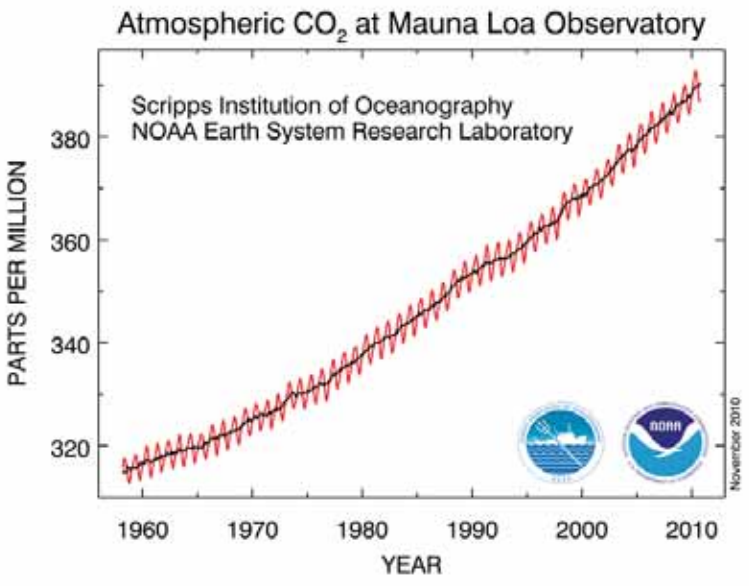
[1]For a very good summary of current knowledge about the Sun, see http://www.nasa.gov/worldbook/sun_worldbook.html (retrieved 9th August, 2010)

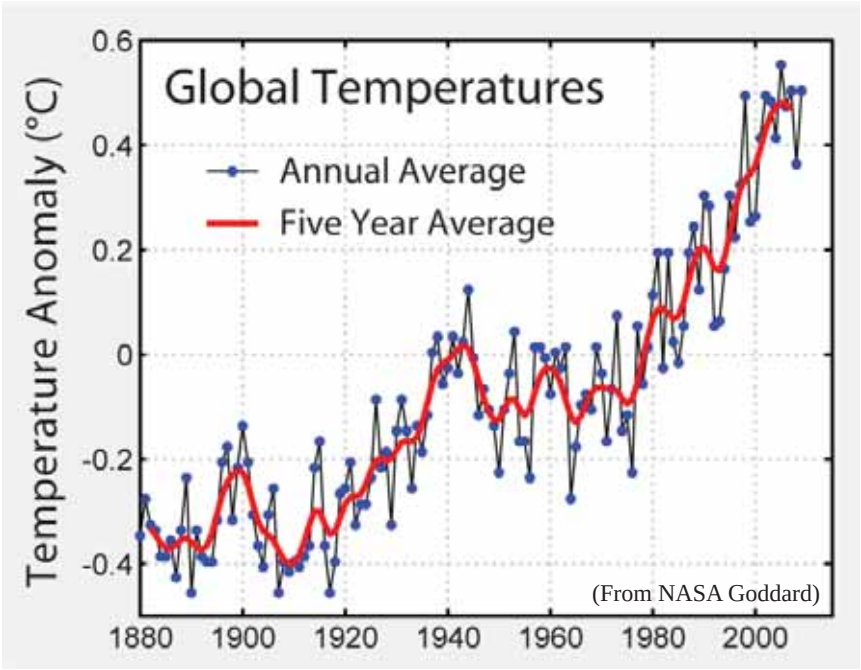
[2]I have simplified, but only slightly. For the outer 70% of the Sun's radius, heat is also transferred by convection. Near the surface, the hydride ion, H-, takes over the role of major absorber and re-emitter of photons. However, hydride does have a high density of accessible energy states, and functions very much in the same way as does plasma at greater depth.

[3]For a more rigorous discussion, see e.g. Supernovae and Nucleosynthesis, David Arnett, Princeton University Press, 1996, Section 2.3. I have ignored the chromosphere because of the relatively small matter that it contains, just as, later, I shall ignore the part of the earth's atmosphere that lies above the tropopause, for much the same reason.

[4]Science 325 (July 2009), 376, and references therein.

[5]http://www.margaretthatcher.org/document/108237 (Retrieved August 13, 2010)





Looking at the two graphs of data, one can clearly see the correlation between the increase in CO_2 and global temperature. There are those who would say that correlation does not imply causation. However, the physics says that in this case the rise in temperature is caused by CO_2 increases that are anthropogenic. We would, in this case, point out that causation *does* imply correlation.

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