Foote vs Tyndall

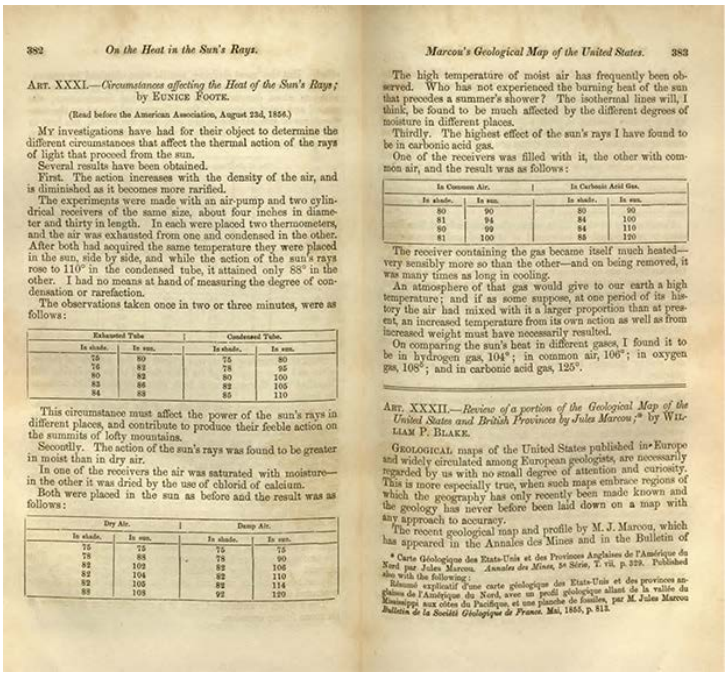
Eunice Newton Foote

In 1856, Eunice Newton Foote, a female American scientist, discovered that carbon dioxide absorbed heat more effectively than other gases. Three years later in 1859, the Irish male physicist John Tyndall arrived at the same conclusion. Though Foote was first to this insight, later known as the greenhouse effect, Tyndall received credit for the discovery. It was not until 2011, 155 years after her experiment, that Foote's discovery was recognized. To examine why this was the case, we must look at their work in the context of the 19th century.

Illustration of Eunice Newton Foote by Carlyn Iverson. Image courtesy of the artist.

Eunice Newton Foote (1819-1888) was a scientist, inventor, and women's rights activist. She attended Troy Female Seminary School and even took courses at a local men's science college. Her first paper, *Circumstances affecting the heat of the sun's rays,* was published in *American Journal of Science and Arts* in 1856 and reported her groundbreaking discovery that carbon dioxide absorbs significantly more heat than other gases. In this experiment, Foote recreated different atmospheric conditions in glass jars and exposed them to the sun. She filled jars with common air, pumping in more air or removing some to compare different densities, adding moisture to others, or even different gases like carbon dioxide. She measured the difference in temperature of the jars in sunlight and of a control jars of each gas left in the shade. Less dense air, like the air found at high elevations on Earth, remained colder than the denser air, a conclusion that had already been experimentally proven. Damp air, she discovered absorbed heat better than dry air. The most striking amount of heat absorption was in carbon dioxide. She concluded in reference to carbon dioxide, "an atmosphere of that gas would give to

our earth a high temperature." Today, it is well established that the warming effect of carbon dioxide and other greenhouse gases causes climate change. Though she came to the correct conclusion, Foote was incorrect that direct sunlight was warming the gases. Foote examined the effects of visible light; however, it is heat in the form of invisible infrared radiation that carbon dioxide absorbs. Still, her discovery of carbon dioxide's power to absorb radiation was groundbreaking.



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ART. XXXI.—*Circumstances affecting the Heat of the Sun's Rays;* by EUNICE FOOTE.

(Read before the American Association, August 23d, 1856.)

MY investigations have had for their object to determine the different circumstances that affect the thermal action of the rays of light that proceed from the sun.

Several results have been obtained.

First. The action increases with the density of the air, and is diminished as it becomes more rarified.

The experiments were made with an air-pump and two cylindrical receivers of the same size, about four inches in diameter and thirty in length. In each were placed two thermometers, and the air was exhausted from one and condensed in the other. After both had acquired the same temperature they were placed in the sun, side by side, and while the action of the sun's rays rose to 110° in the condensed tube, it attained only 88° in the other. I had no means at hand of measuring the degree of condensation or rarefaction.

The observations taken once in two or three minutes, were as follows:

Exhausted Tube.		Condensed Tube.	
In shade.	In sun.	In shade.	In sun.
75	80	75	80
76	82	78	95
80	82	80	100
83	86	82	105
84	88	85	110

This circumstance must affect the power of the sun's rays in different places, and contribute to produce their feeble action on the summits of lofty mountains.

Secondly. The action of the sun's rays was found to be greater in moist than in dry air.

In one of the receivers the air was saturated with moisture—in the other it was dried by the use of chlorid of calcium.

Both were placed in the sun as before and the result was as follows:

Dry Air.		Damp Air.	
In shade.	In sun.	In shade.	In sun.
75	75	75	75
78	88	78	90
82	102	82	106
82	104	82	110
82	105	82	114
83	103	82	120

Marcou's Geological Map of the United States. 383

The high temperature of moist air has frequently been observed. Who has not experienced the burning heat of the sun that precedes a summer's shower? The isothermal lines will, I think, be found to be much affected by the different degrees of moisture in different places.

Thirdly. The highest effect of the sun's rays I have found to be in carbonic acid gas.

One of the receivers was filled with it, the other with common air, and the result was as follows:

In Common Air.		In Carbonic Acid Gas.	
In shade.	In sun.	In shade.	In sun.
80	90	80	90
81	94	84	100
80	99	84	110
81	100	85	120

The receiver containing the gas became itself much heated—very sensibly more so than the other—and on being removed, it was many times as long in cooling.

An atmosphere of that gas would give to our earth a high temperature; and if as some suppose, at one period of its history the air had mixed with it a larger proportion than at present, an increased temperature from its own action as well as from increased weight must have necessarily resulted.

On comparing the sun's heat in different gases, I found it to be in hydrogen gas, 104°; in common air, 106°; in oxygen gas, 105°; and in carbonic acid gas, 125°.

ART. XXXII.—*Review of a portion of the Geological Map of the United States and British Provinces by Jules Marcou;** by WILLIAM P. BLAKE.

GEOLOGICAL maps of the United States published in Europe and widely circulated among European geologists, are necessarily regarded by us with no small degree of attention and curiosity. This is more especially true, when such maps embrace regions of which the geography has only recently been made known and the geology has never before been laid down on a map with any approach to accuracy.

The recent geological map and profile by M. J. Marcou, which has appeared in the Annales des Mines and in the Bulletin of

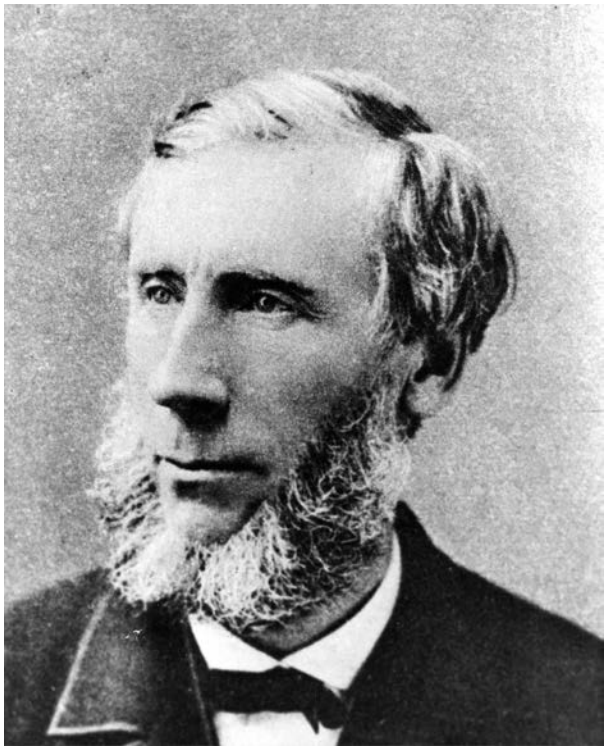
* Carte Géologique des Etats-Unis et des Provinces Anglaises de l'Amérique du Nord par Jules Marcou. *Annales des Mines*, 5e Série, T. viii, p. 329. Published also with the following:

Résumé explicatif d'une carte géologique des Etats-Unis et des provinces anglaises de l'Amérique du Nord, avec un profil géologique allant de la vallée du Mississippi aux côtes du Pacifique, et une planche de fossiles, par M. Jules Marcou *Bulletin de la Société Géologique de France*. Mai, 1855, p. 813.

Eunice Foote's work published in the *American Journal for Sciences and Arts.*

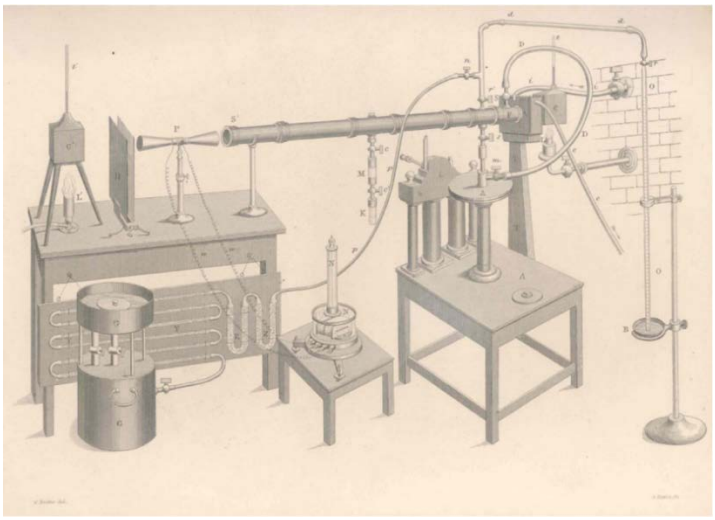
At the American Association for the Advancement of Sciences' (AAAS) 10th meeting, in August 1856, many scientists presented their scientific findings. Elisha Foote, Eunice Foote's husband, even presented his research and was elected as a member. Foote did not present her own work, likely because it was not customary for a woman to speak at these meetings, even though there was no rule against it. Instead, Joseph Henry, the Secretary for the Smithsonian Institution, read her work and provided his own commentary on it. His remarks praised her work but failed to understand its significant implications. Her paper was included in a few publications, including in articles about the AAAS meeting, but was never mentioned in the AAAS proceedings. It is unlikely that these reports and her full paper were read much outside of the United States, and her work was mentioned only twice in European publications. These were short summaries that did not include her conclusion on carbon dioxide's impact on climate. One publication referred to her as Mrs. Elisha Foote and miscredited her work. Her husband's full paper, however, was published by *Philosophical Magazine*, one of the oldest publications in England, even though his conclusions were less significant than hers. Considering his paper was originally published on the page after Eunice Foote's in the *American Journal of Science and Arts*, whoever selected his work must have also seen, and skipped over, hers.

John Tyndall (1820-1893) was already a prominent physicist when he conducted the experiment that revealed carbon dioxide's heat-absorbing power. He received his doctorate in physics at the University of Marburg where he worked among prominent experimental physicists. His access to cutting-edge technology allowed him to use complex, custom-built experimental apparatuses that Eunice Newton Foote could not. He was initially known for his work on magnetism and glaciers and was interested in the molecular structures that absorbed heat. Though he came to the same conclusion as Foote, he was motivated by the study of fundamental physics instead of climate.



Portrait of John Tyndall, Irish Scientist. Image courtesy of AIP Emilio Segrè Visual Archives, E. Scott Barr Collection

His experiment was significantly different from Foote's. He used a spectrophotometer, an instrument that measures the amount of heat absorbed by a material depending on the wavelength of light. He tested the absorption of different gases such as nitrogen, oxygen, hydrogen, and carbon dioxide. He found, like Foote, that carbon dioxide absorbed heat in a way that other gases did not. Understanding the importance of his results, he rushed to announce his findings in 1859 to the Royal Society and published outlines of his preliminary work in several European journals. In 1861, he published the major paper with his results but made no mention of its climate applications.



John Tyndall's experimental apparatus.[1]

Debate remains whether Tyndall was aware of Foote's work. There is a multitude evidence indicating that he was uninformed of her conclusions. He appeared surprised by his results on carbon dioxide and had even hypothesized other gases would absorb more heat. Tyndall and other physicists conducted similar research at the same time, and even argued with each other for credit of the discovery. Their correspondence discussing the research done in the field made no mention of Foote. These actions make it seem unlikely that he knew of her work and discovery. However, Tyndall would have been exposed to her work. One of his papers was published in the same journal as Foote's, meaning he was aware of the publication and may have even read through it. Additionally, Tyndall was on the editorial board of *Philosophical Journal*, the publication that selected Foote's husband's work and not hers. As an editor of this publication and would have been involved in the selection process. Perhaps Tyndall saw and never read her paper, something that would be improbable if he was pursuing a similar field of research. Perhaps, like Joseph Henry, who read her work for AAAS, he did not understand her results. For now, there is only speculation.

In the early to mid-19th century, the United States did not have a well-established or globally revered scientific community. At the time, the United States was in the beginning phases of establishing scientific societies and infrastructure. The Smithsonian Institution was founded just a decade earlier in 1846 and the AAAS was not founded until 1848. The National Academy of Sciences would not be founded until 1863. Though there were some internationally regarded scientists in the United States such as Benjamin Franklin, Europe was seen as the center of major scientific work, especially in the field of physics. This posed issues for American scientists as it was difficult and uncommon to travel across the Atlantic Ocean, and information moved slowly. To publicize their work across the ocean, American scientists needed connections in Europe, something an amateur, female, scientist like Eunice Foote

[1] Retrieved from: Jackson, Ronald. "Eunice Foote, John Tyndall and a Question of Priority." *The Royal Institution* 74, no. 1 (February 13, 2019): 105–18. https://doi.org/10.1098/rsnr.2018.0066.

likely would not have had. Her location and lack of connections would have made it difficult for her to publicize her findings globally.

The United States' international reputation likely impacted the reception of her work, but undoubtedly so did her gender. Most American colleges and universities did not admit women, so she was prevented from receiving a higher level of education, connections with foreign scientific contemporaries, and the equipment resources that Tyndall had. She likely did not present her own work at the AAAS meeting because she was a woman, and Henry's remarks about her work not only missed its significance but were viewed as patronizing. Tyndall himself believed women were less capable scientists than men. Luckily, today we recognize her important contribution to science and give her the credit she deserves.