Franklin and Electrostatics-
Ben Franklin as my Lab Partner

A Workshop on Franklin's Experiments in Electrostatics

Developed at the Wright Center for Innovative Science Teaching
Tufts University
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Sept. 2004

IX. Electrical experiments made in pursuance of those made by Mr. Canton

Franklin's experiments on electrostatic induction based on his idea of the 'electric atmosphere' of charged bodies.

ELECTRICAL EXPERIMENTS

Made in Pursuance of those made by Mr. Canton, dated December 6, 1753; with Explanations, by Benjamin Franklin

Bigelow Vol. III, CXV pp 60-67

READ AT THE ROYAL SOCIETY, DECEMBER 18, 1755

PHILADELPHIA, 14 March, 1755

PRINCIPLES:

14.01

I. Electric atmospheres that flow round non-electric bodies, being brought near each other, do not readily mix and unite into one atmosphere, but remain separate and repel each other.

14.02

This is plainly seen in suspended cork balls and other bodies electrified.

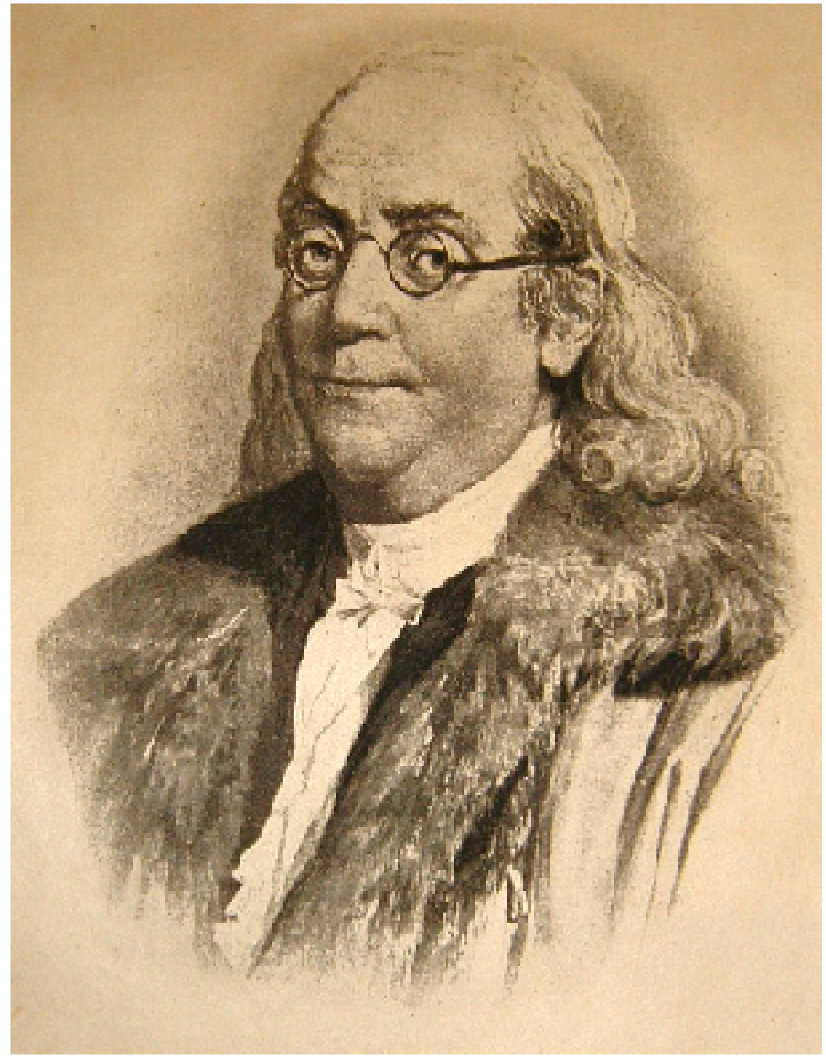
Franklin envisions an 'electric atmosphere' surrounding the outside of a conductor which stays attached to the electric fluid in a conductor. As an example, two cork balls which are electrified positively repel each other, rather than coming together as one.

14.03

II. An electric atmosphere not only repels another electric atmosphere, but will also repel the electric matter contained in the substance of a body approaching it, and, without joining or mixing with it, force it to other parts of the body that contained it.

14.04

This is shown by some of the following experiments.



Benjamin Franklin from the painting by Greutze
Bigelow, 1904, Vol. 12, frontispiece
(public domain)

14.05

III. Bodies electrified negatively, or deprived of their natural quantity of electricity, repel each other (or at least appear to do so by a mutual receding), as well as those electrified positively, or which have electric atmospheres.

14.06

This is shown by applying the negatively charged wire of a phial to two cork balls suspended by silk threads, and many other experiments.

This letter is an example of demonstrating the application of theory by giving a series of experiments which are can be accounted for by the theory. They are interesting because they lead to the concept of electrostatic induction, later employed by Alessandro Volta in the invention and application of the electrophorus.

Movie file: 13. Electrostatic Induction

14.07

Fix a tassel of fifteen or twenty threads, three inches long, at one end of a tin prime conductor (mine is about five feet long and four inches diameter) supported by silk lines.

14.08

Let the threads be a little damp, but not wet.

14.09

Pass an excited glass tube near the other end of the prime conductor, so as to give it some sparks, and the threads will diverge.

14.10

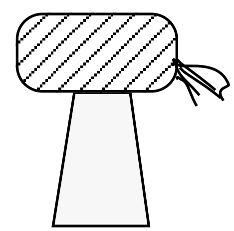
Because each thread, as well as the prime conductor, has acquired an electric atmosphere, which repels and is repelled by the atmospheres of the other threads; if those several atmospheres would readily mix, the threads might unite, and hang in the middle of one atmosphere, common to them all.

In Franklin's theory, the repulsion of positively charged objects, which in his view have extra electric fluid, is due to the particles of the electric fluid repelling each other. However, since normal matter was supposed to attract electric fluid, it was not clear why a lack of electric fluid, which is what he meant by negatively charged, should lead to the repulsion of objects – hence his statement that they "appear to do so by a mutual receding."

Note that only bodies with positive charge have electric atmospheres.

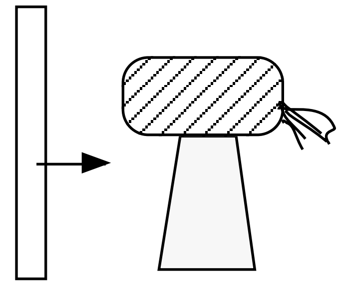
You may use your prime conductor, but a soda can taped to a foam cup is more convenient. Instead of damp threads, we will use holiday tree tinsel. Take two lengths of tinsel, double them and redouble them, then stick a piece of tape over one end. Cut the loops off the other end and you will have a bunch of eight tinsel strips. Attach it to the end of the can with the tape. You may use a thread tassel as Franklin describes if you wish.

Rub a PVC tube and bring it near the other end of the can. Let it spark. What happens?



14.11
Rub the tube afresh, and approach the prime conductor therewith, crosswise, near that end, but not nigh enough to give sparks, and the threads will diverge a little more.

Try it. Does it happen as Franklin says?

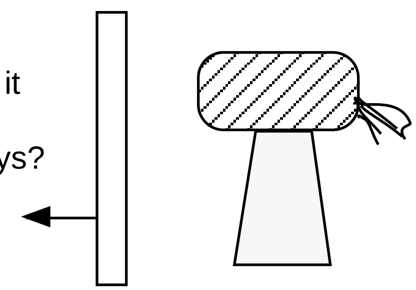


14.12
Because the atmosphere of the prime conductor is pressed by the atmosphere of the excited tube, and driven towards the end where the threads are, by which each thread acquires more atmosphere.

Franklin envisions the excess charge in the tube and the excess charge in the can as each having an electric atmosphere that extends some moderate distance from the object. These atmospheres push against each other, so moving the tube close shoves the atmosphere of the can which moves more of the associated electric fluid and its atmosphere into the tinsel, shoving the tinsel leaves farther apart.

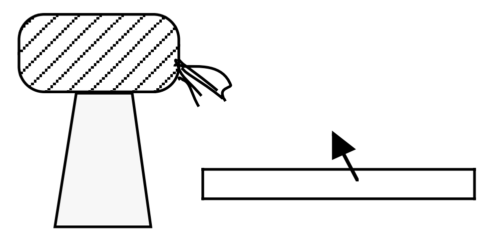
14.13
Withdraw the tube, and they will close as much.

Try it. Does it happen as Franklin says?



14.14
They close as much, and no more, because the atmosphere of the glass tube, not having mixed with the atmosphere of the prime conductor, is withdrawn entire, having made no addition to or diminution from it.

14.15
Bring the excited tube under the tuft of threads, and they will close a little.



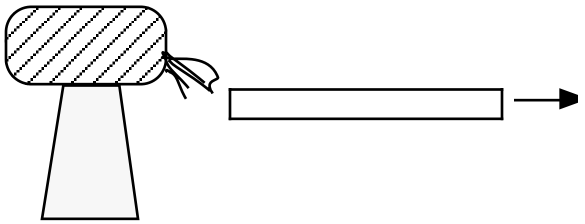
14.16
They close, because the atmosphere of the glass tube repels their atmospheres, and drives part of them back on the prime conductor.

14.17

Withdraw it, and they will diverge as much.

14.18

For the portion of atmosphere which they had lost returns to them again.



Franklin's notion of an electric atmosphere is a precursor of Michael Faraday's idea of lines of electric force, which leads to Maxwell's mathematical development of the concept of the electric field.
Neither Franklin nor Faraday had much formal training in mathematics, but they both successfully used visualization as a theoretical tool to explain the phenomena they observed.

14.19

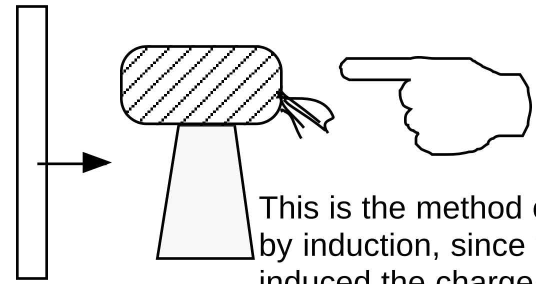
Excite the glass tube and approach the prime conductor with it, holding it across, near the end opposite to that on which the threads hang, at the distance of five or six inches. Keep it there a few seconds, and the threads of the tassels will diverge. Withdraw it, and they will close.

14.20

They diverge, because they have received electric atmospheres from the electric matter before contained in the substance of the prime conductor, but which is now repelled and driven away by the atmosphere of the glass tube from the parts of the prime conductor opposite and nearest to that atmosphere, and forced out upon the surface of the prime conductor at its other end, and upon the threads hanging thereto. Were it any part of the atmosphere of the glass tube that flowed over and along the prime conductor to the threads, and gave them atmospheres (as is the case when a spark is given to the prime conductor from the glass tube), such part of the tube's atmosphere would have remained, and the threads continue to diverge; but they close on withdrawing the tube, because the tube takes with it *all its own atmosphere*, and the electric matter, which had been driven out of the substance of the prime conductor, and formed atmospheres round the threads, is thereby permitted to return to its place.

This repeats the experiment of 14.11 through 14.14 with more explanation, getting ready for a new experiment in 14.21.

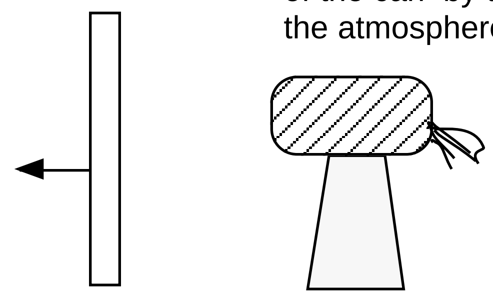
14.21
Take a spark from the prime conductor near the threads, when they are diverged as before, and they will close.



14.22
For by so doing you take away their atmospheres, composed of the electric matter driven out of the substance of the prime conductor, as aforesaid, by the repellency of the atmosphere of the glass tube. By taking this spark you rob the prime conductor of part of its natural quantity of the electric matter, which part so taken is not supplied by the glass tube, for, when that is afterwards withdrawn, it takes with it its whole atmosphere, and leaves the prime conductor electrized negatively, as appears by the next operation.

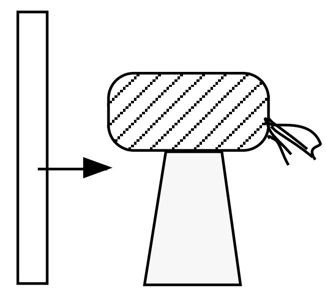
This is the method of charging by induction, since you have induced the charge to move out of the can by the influence of the atmosphere of the tube.

14.23
Then withdraw the tube, and they will open again.



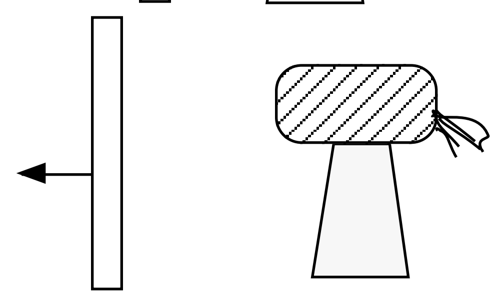
14.24
For now the electric matter in the prime conductor returning to its equilibrium, or equal diffusion, in all parts of its substance, and the prime conductor having lost some of its natural quantity, the threads connected with it lose part of theirs, and so are electrized negatively, and therefore repel each other by *Principle* III.

14.25
Approach the prime conductor with the tube, near the same place as at first, and they will close again.



14.26
Because the part of their natural quantity of electric fluid which they had lost is now restored to them again, by the repulsion of the glass tube forcing that fluid to them from other parts of the prime conductor; so they are now again in their natural state.

14.27
Withdraw it, and they will open again.



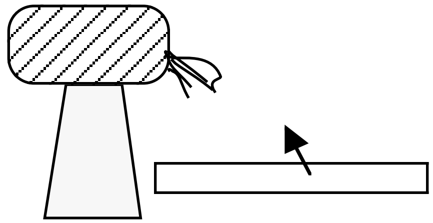
14.28
For what had been restored to them is now taken from them again, flowing back into the prime conductor, and leaving them once more electrized negatively.

14.29

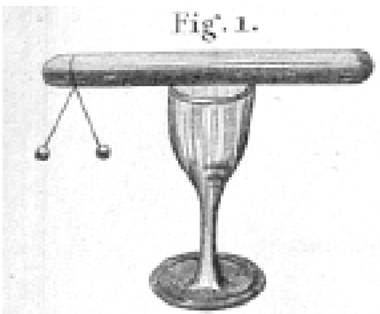
Bring the excited tube under the threads, and they will diverge more.

14.30

Because more of their natural quantity is driven from them into the prime conductor, and thereby their negative electricity increased.



Contrast this with the experiment in 14.15



Detail of similar experiment using cork balls suspended from an insulated conductor.

George Adams & William Jones, 1799, Vol V, Plate I
Lectures on Natural and Experimental Philosophy, London
The Burndy Library,
Dibner Institute for the History of Science & Technology
Cambridge, Massachusetts

14.31

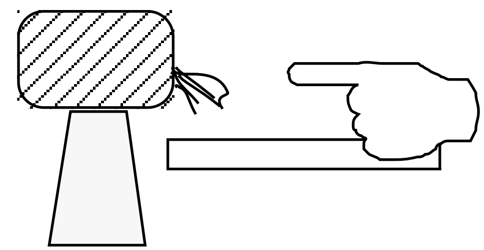
The prime conductor not being electrified, bring the excited tube under the tassel and the threads will diverge.

14.32

Part of their natural quantity is thereby driven out of them into the prime conductor, and they become negatively electrized, and therefore repel each other.

14.33

Keeping the tube in the same place with one hand, attempt to touch the threads with the finger of the other hand and they will recede from the finger.



14.34a

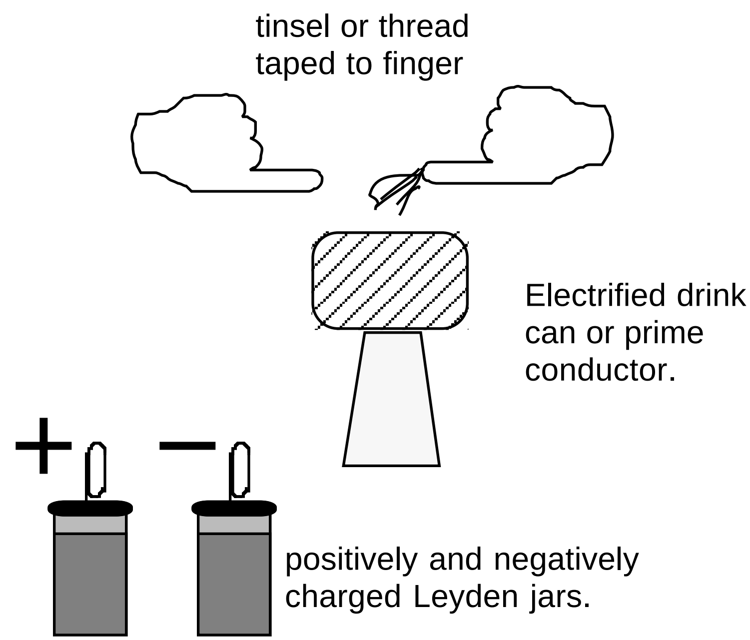
Because the finger being plunged into the atmosphere of the glass tube, as well as the threads, part of its natural quantity is driven back through the hand and body by that atmosphere, and the finger becomes, as well as the threads, negatively electrized, and so repels, and is repelled by them.

14.34b

To confirm this, hold a slender, light lock of cotton, two or three inches long, near a prime conductor that is electrified by a glass globe or tube. You will see the cotton stretch itself out towards the prime conductor. Attempt to touch it with the finger of the other hand, and it will be repelled by the finger.

14.34c.

Approach it with a positively charged wire of a bottle, and it will fly to the wire. Bring it near a negatively charged wire of a bottle, it will recede from that wire in the same manner that it did from the finger; which demonstrates the finger to be negatively electrized, as well as the lock of cotton so situated.



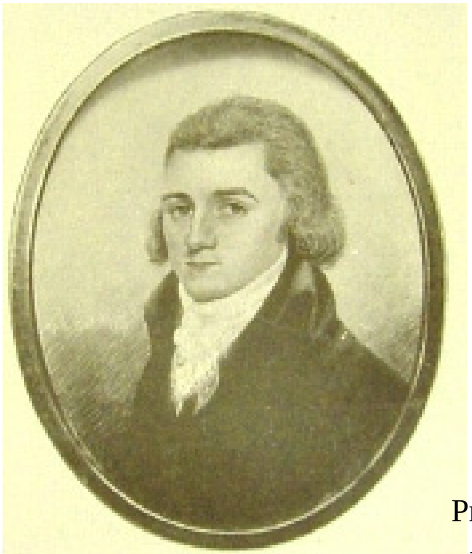
14.35

Turkey killed by Electricity–Effect of a Shock on the Operator in making the Experiment

As Mr. Franklin, in a former letter to Mr. Collinson, mentioned his intending to try the power of a very strong electrical shock upon a turkey, that gentlemen accordingly has been so very obliging as to send an account of it, which is to the following purpose:

14.36
He made first several experiments on fowls, and found that two large, thin glass jars gilt, holding each about six gallons, were sufficient, when fully charged, to kill common hens outright; but the turkeys, though thrown into violent convulsions, and then lying as dead for some minutes, would recover in less than a quarter of an hour. However, having added three other such to the former two, though not fully charged, he killed a turkey of about ten pounds weight, and believes that they would have killed a much larger. He conceited, as himself says, that the birds killed in this manner eat uncommonly tender.

14.37
In making these experiments, he found that a man could, without great detriment, bear a much greater shock than he had imagined; for he inadvertently received the stroke of two of these jars through his arms and body, when they were very near fully charged. It seemed to him a universal blow throughout the body from head to foot, and was followed by a violent, quick trembling in the trunk which went off gradually in a few seconds. It was some minutes before he could recollect his thoughts as to know what was the matter; for he did not see the flash, though his eye was on the spot of the prime conductor, from whence it struck the back of his hand; nor did he hear the crack, though the by-standers said it was a loud one; nor did he particularly feel the stroke on his hand, though he afterwards found it had raised a swelling there of the bigness of half a pistol-bullet. His arms and the back of the neck felt somewhat numbed the remainder of the evening, and his breast was sore for a week after, as if it had been bruised. From this experiment may be seen the danger, even under the greatest caution, to the operator, when making these experiments with large jars; for it is not to be doubted but several of these fully charged would as certainly, by increasing them in proportion to the size, kill a man, as they before did a turkey.



GOVERNOR JAMES BOWDOIN
By Edward G. Malbone
Lent by Mrs. Joseph Grafton Minot

James Bowdoin, II
Bulletin of Society for Preservation of New England Antiquities, Vol. V, no. 1, April, 1914
(public domain)

There are two accounts of Franklin's attempts to kill a turkey. This one was published in his book, because the letter in which he described his experience had been lost.

The missing letter was later found (among the papers of Governor James Bowdoin of Massachusetts) and appears on the next page, in Franklin's own words.

14.38

Bigelow *vol. II, LXXVI* *pp. 325-326*

To A Friend in Boston

Philadelphia, 25 December, 1750.

I have lately made an experiment in electricity that I desire never to repeat. Two nights ago, being about to kill a turkey by the shock from two large glass jars, containing as much electrical fire as forty common phials, I inadvertently took the whole through my own arms and body, by receiving the fire from the united top wires with one hand, while the other held a chain connected with the outsides of both jars. The company present (whose talking to me and to one another, I suppose, occasioned my inattention to what I was about) say that the flash was very great, and the crack as loud as a pistol; yet, my senses being instantly gone, I neither saw the one nor heard the other; nor did I feel the stroke on my hand, though afterwards found it raised a round swelling where the fire entered, as big as half a pistol-bullet, by which you may judge of the quickness of the electrical fire, which by this instance seems to be greater than that of sound, light, or animal sensation.

14.39

What I can remember of the matter is that I was about to try whether the bottles or jars were fully charged by the strength and length of the stream issuing to my hand, as I commonly used to do, and which I might safely enough have done if I had not held the chain in the other hand. I then felt what I know not how well to describe—a universal blow throughout my whole body from head to foot, which seemed within as well as without; after which the first thing I took notice of was a violent, quick shaking of my body, which gradually remitting, my sense as gradually returned, and then I thought the bottles must be discharged, but could not conceive how, till at last I perceived the chain in my hand, and recollected what I had been about to do. That part of my hand and fingers which held the chain was left white, as though the blood had been driven out, and remained so eight or ten minutes after, feeling like dead flesh; and I had a numbness in my arms and the back of my neck, which continued till the next morning, but wore off. Nothing remains now of this shock but a soreness in my breast-bone, which feels as if it had been bruised. I did not fall, but suppose I should have been knocked down if I had received the stroke in my head. The whole was over in less than a minute.

14.40

You may communicate this to Mr. Bowdoin as a caution to him, but do not make it more public, for I am ashamed to have been guilty of so notorious a blunder; a match for that of the Irishman whom my sister told me of, who, to divert his wife, poured the bottle of gunpowder on the live coal; or of that other, who, being about to steal powder, made a hole in the cask with a hot iron. I am yours, &c.,

B. FRANKLIN

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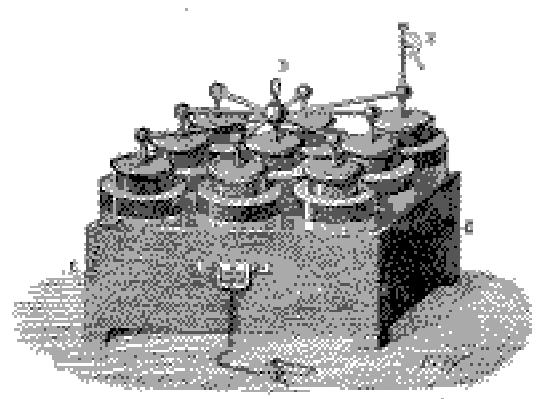
P.S.—The jars hold six gallons each.

A copy of this letter was found among Governor Bowdoin's papers, without the name of the person to who it was addressed. —Sparks.

Large Leyden Jar c 1830. R. Morse photograph.
Collection of
The Burndy Library,
Dibner Institute for the History of Science & Technology
Cambridge, Massachusetts

A large Leyden jar of the sort Franklin used to try to kill a turkey by electrocution. This one would have a liquid capacity of about 6 gallons. Franklin used a number of these connected together to form what he dubbed an “electric battery”, as shown in the figure below.



Foster, G. C., Atkinson, E., *Elementary Treatise on Electricity and Magnetism, founded on Jaubert's Traite Elementaire d'Electricite*, London, Longmans Green and Co., 1896, p. 77 (public domain)