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TORNBERN BERGMAN'S THUNDERSTORM LECTURES

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ABSTRACT

This article describes and analyzes the importance of Tornbern Bergman's inaugural lecture given to the Swedish Royal Society in 1764 on preventing the destructive effects of thunderstorms.

RERSUMO

Este trabalho descreve e analisa a importância da conferência inaugural de Tornbern Bergman perante a Acadêmia Real da Suécia em 1764 sobre a prevenção e efeitos destrutivos dos trovões.

In the process of preparing a translation from Swedish of Torbern Bergman's Inaugural Lecture to the Swedish Royal Socity on "Preventing the Destructive Effects of Thunderstorms" (1), I became very much aware of the international nature of research on lightning and other effects of thunderstorms in this period over two centuries ago. Benjamin Franklin was publishing his famous experiment with the kite in 1752 (2), at about the same time that Bergman began his own experiments on electricity that resulted in his inaugural lecture on the occasion of his being taken into the Swedish Royal Society in 1764. And at about the same time in Russia, Georg Wilhelm Richman (1711-1753) was undertaking his experiments on natural electricity that resulted in his dramatic death by electrocution while he was carrying out such an experiment.

We can get the best description of Franklin's kite experiment in his own words, from his letter to Peter Collinson, Esq., F.R.S. (2):

> "Make a small cross of two light strips of cedar, the arms so long as to reach to the four corners of a large thin silk handkerchief when extended: tie the corners of the handkerchief to the extremities of the cross, so you have the body of the kite; which being properly accomodated with a tail, loop, and string, will rise in the air, like those made of paper; but this being of silk is fitter to bear the wet and wind of a thunder-gust without tearing. To the top of the upright stick of the cross is to be fixed a very sharp pointed wire, rising a foot or more above the wood. To the end of the string, next to the hand, is to be tied a silk ribbon, and where the silk and twine join, a key must be fastened. This kite is to be raised when a thunder-gust appears to be coming on, and the person who holds the string must stand within a door or window, or under some cover, so that the silk ribbon

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> may not be wet; and care must be taken that the twine does not touch the frame of the door or window. As soon as any of the thunder clouds come over the kite, the pointed wire will draw the electric fire from them, and the kite, with all the twine, will be electrified, and loose filaments of the twine will stand out every way, and be attracted by an approaching finger. And when the rain has wet the kite and twine, so that they can conduct the electric fire freely, you will find it stream out plentifully from the key on the approach of your knuckle. At this key the phial may be charged; and from electric fire thus obtained, spirits may be kindled, and all the other electric experiments be performed, which are usually done by the help of a rubbed glass globe or tube, and thereby the sameness of the electric matter with that of lightning be completely demonstrated."

We can only marvel at Franklin's good fortune in carrying out this experiment, in which he exposed himself to the same extreme danger of lightning stroke that caused the death of Richman.

Since Richman was not around to describe his fatal experiment, we have to depend on the deposition of an engraver for the Royal Society, I. Sokolov, who was present at the time (see Ref. 1, Note (n)):

> "Professor Richman in Petersburg in the previous year (1752) had prepared for the start of his investigations, and he was especially engaged with them in measuring artificial and meteoritic electricity and comparing them with each other. On 9 Aug 1752 all his equipment became so electrified that he trembled as from cold, and the spark moved backwards up his arm. On 31 May 1753 the electricity crackled so loudly that those in the third room from his could hear it. Alone on the 6th of Auygust (1753), he came to his unfortunate hour, when his investigations and his life ended at the same time, as we were informed in detail (see Note (bb) (1))...
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> "Note (bb) <u>Professor G.W. Richman belongs under the first [category] which Dalibord's experiments imitated.</u> He knocked a hole in the bottom of a bottle and inserted an iron rod, which was fastened in the neck [of the bottle] with a cork. After this a roof tile was removed on the north side of the house, and the bottle was fixed in its place, and held by the tile lying on top of it; and all was arranged so that the point of the [iron] rod reached four to five feet above the roof. The lower end of the rod did not touch any grounded body, since it was fastened to the same iron chain which, supported by silk cords, was led into his [Richman's] chamber. The window of the room faced

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toward the south, and against the window stood a table, four feet high, on which the electric detector (gnomon) [electrometer] was placed. The detector stood on a small iron rod, which was supported on a glass base filled with iron filings as detectors. A twine cord, one and one-half feet long, with a grain of lead at the end, was fastened to the small rod at the top. This hanging piece hung at right angles, or nearly so, as long as it was not electrified. A quadrant divided into degrees, which were two lines [2 Linien = 4 mm] in size, lay against the twine cord, and in such a way that the midpoint of the curve rested against the cord. Since the chain was connected to this small rod, one could immediately detect if the rod were electrified; for then the cord of the plumb line was driven up [the scale], and the stronger the charge the farther it was driven. Mr. Richman compared the strength of meteoritic electricity with artificial [electricity] and found the latter to be greater; for the cord could be driven 55 degrees up [the scale] by it [artificial], whereas the former [meteoritic] never more than 30 degrees. Sometimes he even used a detector which was connected to the inside of a Leiden flask [jar], and a second detector connected to the outside of the same flask. On 6 August 1753 his installation was again electrified, and with it he used only one detector, with which he could observe to what degree the cord was driven up; but at that very instant a fire-ball, as large as a fist, was led by the small iron chain towards his head, which was one foot away from it, and struck him dead to the ground. The explosion was like a small cannon shot. An iron wire, which connected the chain to the iron rod, exploded, and a piece of it burned the clothes of your Academy's engraver, Sokolora, who stood nearby. Richman had in his pocket 70 Rubel, which were not damaged. See Winkler's Programma, and Lomonosov's Orat. de Meteor., vi electr. ortis.

> Richmanni funus multa cavere jubet.
> Dum tangit ferrum rapitur super aethera
> doctor
> Ac inter Physices sidera latus erat.

> [The death of Richman shows us much that should be avoided. When he touched iron the doctor was snatched to heaven. And at the same time, Physics was related to the stars.]

Bergman's Thunderstorm Lecture.

"The mistake in his installation was this, that the lightning was carried into the room, with no off-conductor provided beforehand in the event of violent danger. If a chain leading out from the installation, even one quarter the size of that chain which brought the electricity inside, had been prepared, then the spark would hit the out-conducting chain as soon as it became at all dangerous, and in no way would such a diligent investigator have been killed."

Bergman described the effects of lightning strokes very vividly in his lecture:

"The strongest towers and walls are very often shattered in an instant (c); our churches and dwellings are set afire, destroyed, and quite often changed into an ash-heap (d); the floating habitations of sea-farers are also sometimes struck, whereupon the self-same inhabitant must cast his lot either with fire or water (e); if the ship is undamaged, yet still is that direction indicator, namely the compass, destroyed or made unruly (f); the best and longest ropes are broken into pieces, or torn into countless parts (g); animals are slain (h), friends and next of kin are injured, and often, close beside us, fall lifeless to the ground (i); and we count ourselves very lucky if our own body escapes uninjured from this danger which threatens us...

"... then Doctor Franklin proposed a means by which to ascertain fully the truth of these things (m). A trustworthy experiment had taught him that a metal point, held at a fixed distance from an electrified body, attracted to itself more or less of the [electrical] power; from which it was evident that if this rubbed point were isolated from electrically conducting bodies adjacent to it by means of glass, sealing wax, silk, and the like, then because of this the electricity would hardly allow itself to be conducted away. If we now erected [such] pointed iron rods provided with glass supports on high places, and thunderclouds passed over them, then if this parcel of air were electrified and not too high above, the same force must collect itself in the rod and would then reveal itself through sparks, etc."

The letters in parentheses refer to Bergman's Notes appended to his lecture proper (see Ref. 1).

Bergman then described the difference between non-conducting substances such as glass, sealing wax, pitch, and silk, and conducting substances such as metals, water, and animal bodies. He described an experiment he made to determine the speed with which electricity was conducted through metals:

> "An attempt has been made at measurement, in which this electrical force was conducted forwards for more than 900 Swedish fathoms [5400 feet] without the slightest difference in time being noted between the moments when the force showed itself at the nearest end and at the farthest end. Metals conduct this force most perfectly of all substances, insofar as we know up to now; and I have, in a paper submitted to the Royal Society, shown that a cylinder of water of three decimal lines diameter [9 mm] does not have the capacity to conduct away the entire charge on a small electrified glass [globe?], while in comparison a small strip of gold leaf of the same width does it perfectly. In addition it may be added that lightning matter is not as abundant as was once thought; that the point [of a rod] attracts it [electrical matter] from a long distance before the clouds reach it [the rod] and come to stand over it midway, which [clouds] will then largely discharge through it before they come to their zenith, or to the point where danger is the greatest; and finally that the conducting power of metals exceeds all known limits; and so it becomes possible for us to believe that the thunderstorm can be averted to a considerable extent.
>
> "If the bank or side of a stream could be provided with a channel in which water could be sucked and carried away with a velocity such as that with which a metal rod carries electricity, it is my conviction that floods would cause no particular damage in surrounding regions. We must not however overlook the reasonable conclusion that this is derived from some already known and accepted principles; in particular, we should proceed to investigate whether we have not already learned something from experience, namely if we can find any conclusive evidence that the thunderstorm may actually be turned away sometimes without doing any damage; and then under what circumstances this occurs."

He then described Franklin's experiments with lightning rods in Philadelphia. Then he asked a crucial quuestion:

Bergman's Thunderstorm Lecture.

"If we now ask: 'Why do thunderbolts not spare the churches and castles that are now armed with iron points?', then we can answer reasonably: the cause is the lack of an adequate conductor attached to it. For example, if a quantity of metal roof ornaments are fastened to a [dry] wall, then that electricity which they collect cannot be lost because a dry brick wall will not conduct away the electrical power: and, as so often happens, if the power is increased sufficiently, the sparks can jump to the nearest metal or conducting body, and also at the same time setting fire to anything inflammable lying in the way (a). If now this new conductor is itself detached [from the ground], then fire can occur in a third place, and so on. In this way it happens that one stroke starts fires in several places at the same time. The fate of Professor Richman in Petersburg (bb) testifies sufficiently about this (cc), as to what we risk if we lack a conductor.

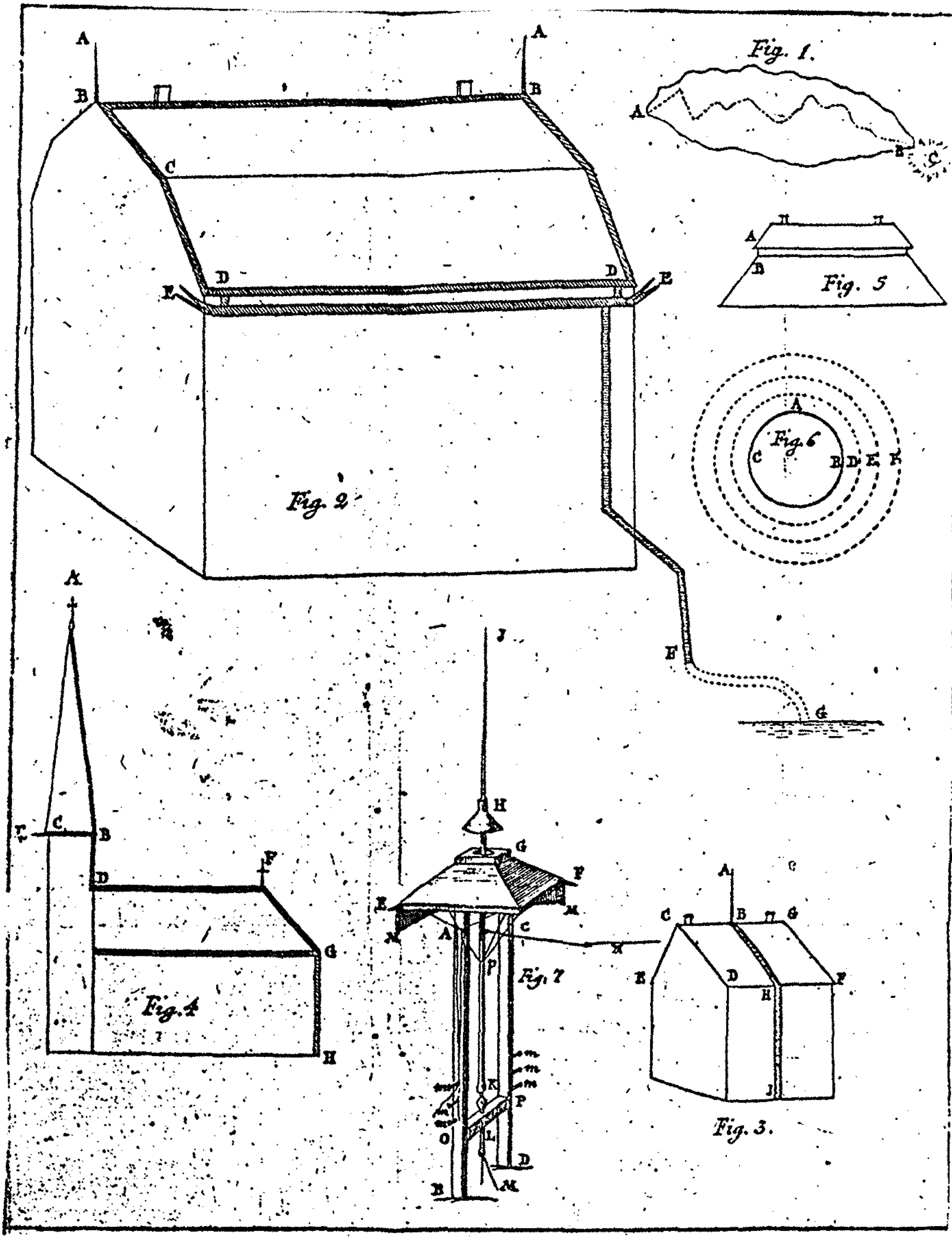
"I had occasion a year ago to be convinced of this fact in a similar incident. The Marienstadt Church is tall, and in addition is situated very conspicuously by itself: the new roof and likewise the new steeple are covered with sheets of iron, and the latter [the steeple] is now provided with five high-standing iron rods which have stars on the ends. We expected from all this that the steeple would attract to itself some lightning material from thunderclouds passing by, which would strike so much more dangerously because the great church roof and the roof of the steeple had no metal connector [to the ground]. In the summer of the year 1762, I expressed to the church authorities my concern about this. But they seemed to attach little importance to this, and especially in this case because the new steeple was constructed much lower than the old one had been, and such was also the case with the rafters of the roof. But lightning struck four days afterwards, and the stroke took exactly the path that I had predicted, namely from the steeple it led down to the great roof, from which it passed down to the inside of the wall, which workmen were still cementing with lime, and from there it passed from the wall on the north side down to the earth. If the mortar had had more time to dry, the stroke would have found no conductor down from the great church roof, and would undoubtedly have set fire then to something in the steeple. Moreover, it is especially worthy of attention, that that side of the church wall which faced particularly towards the north, and thus was divested less of its moisture by the sun, conducted away completely the fire of the stroke from the roof, and thereby prevented any further damage (y)."

Bergman then discussed the moral implications of erecting protective devices against the thunderstorm:

"It is not physics, but has to do with legality, how to justify it, if we are going to do this as things now stand. Some would put the defense against the thunderstorm in the same class with innoculation against chicken pox, and consider it to be impious, mistaken, and not for mere mortals; like a council of ogres wishing to attack the heavens. The innate corruption of men condemns them to be unworthy of doing good, and their lack of gratitude toward the Omnipotent God is such that, with fearful hearts, they ought to regard the perils hanging over their heads as being the well-deserved consequences of the evil they have committed. The Lord of Nature has himself ordained the lightning for His own purposes, in order to threaten and punish thereby the earth's inhabitants; so it would be unthinkable if now thunder and lightning could not occur in the very places where the greatest sin had been committed. This is undoubtedly the correct attitude, the right direction and the best ultimate purpose of physics, in addition to the ethics common to all other fields which, in view of the lowly nature of man, can best describe the omnipotence of the Creator. But, on the other hand, I have never heard that anybody has yet refused to protect themselves against infectious diseases, or earthquakes, or typhoons or other similar hazardous occurrences. So, if this kind of thing is permitted, why then could we not also seek to protect our property, our health, and our lives against the thunderstorm, if we can find the means to do so? Now enough of this one particular subject!"

He then described a proper installation for protection against lightning strokes, and a conductor connected to it to carry the charge to the ground:

"On each end of the beam which forms the ridge or point of the roof, and to which all rafters of the roof are attached, is fastened a flat or round iron rod, a few ells in length, with a gilded point; or if we wish, we can equip the end of this iron rod with a metallic sphere, which has spikes or barbs protruding outwards



FIGURES 1-7. FIGURES THAT APPEARED IN BERGMAN'S PUBLISHED LECTURE TO ILLUSTRATE VARIOUS TYPES OF LIGHTNING ROD INSTALLATIONS.[1]

all around it, upon which the electricity can spurt from all sides. (Many springs flow fuller and easier than a few.) In order to prevent rust on these spikes and the rod, they must ne gilded, for it has been found that rust obstructs the passage of the electrical material.

"If the roof is covered completely with metal plates, it is necessary to provide only a metallic connection between the roof and the ground and soil. A similar connection may be provided for a tiled roof which is covered with iron plates at the points and ridges, the edges and the foot of the gables; and where such metallic facings are missing they must be constructed.

"In order to conduct the lightning matter down on the walls of buildings, we must sheath the main corners, or at least two corners situated diagonally opposite to each other, with a facing of tinned sheet-iron, which must be connected to the roof plates. If there are sheet-metal gutters under the roof, then these should be connected to the roof plates, and no facing of sheet-iron is then needed over the edges of the walls in such a case. If possible, everything which is of metal on the outside of the bilding must be connected together, so that a continuous conductor is provided.

"If the building is very tall so that the clouds can occasionally touch the battlements, for the sake of greater security, one or more points are erected at the bottom of the roof, which points must project at the edges of the roof. On the whole it must be stated that metal points must never be lacking on the outer trimming of churches and other important buildings. Earth and sand are substances which, taken by themselves alone, are too dry to conduct the electricity. Thus it is not sufficient to provide a connection between the endangered object and the earth; for still more [attention] is required here. In this case one or more tinned pipes should be prepared, which are connected to the water-spouting, or with the sheet-metal roof facing at the corners, and which [pipes] must be long enough so that they can reach to the water lying closest at hand, it may be a brook, a trench, or a river, in which the lightning material can be carried away, if the clouds are active (jakada), or [the kind] from which enough moderated (blikande) matter can be obtained if they are inactive (nekada) (kk). Plates and pipes are most suitable for this contrivance, because experience teaches us that the larger the surface is the more electrical matter it can accomodate."

Bergman even described how you could protect yourself in an open field:

"If one finds himself in an open field it is not advisable for him to continue on his way (ll); nor should he seek refuge under high trees (g). If he can reach a house, which is protected in the aforesaid manner, then he obtains the greatest degree of safety; for the advantage which one gains from wet clothing, is obtained very easily at the same time, though often against our will; worst of all is the inconvenience that we can never free ourselves from peril because our body is at least as good a conductor as wet clothes. It is somewhat different with houses and buildings of stone, whose walls in themselves are not serviceable as conductors; for a heavier rain can make the walls at times conducting, and the building is in this way preserved instead of being destroyed by the event. A naked sword or small iron spike held over the head is likewise a means which can bring not only advantage but also harm; for if the lightning strikes upward or downward through the sword, then a limb of the human body will be in the path or course of the lightning material, and perhaps for the last time. More trustworthy, even though inconvenient to carry with you, would be a properly adapted umbrella (mm)."

Note (mm) referred to reads as follows:

"(mm) Mr. Franklin believes that we would be sufficiently protected against lightning in an open field if we would make our clothes wet or moist; and the reason for this is that no wet rats have ever lost their lives from electrical stroke. I have indeed, up to now, never thought about making an investigation of this [theory]; however it is known that fish die in a tank if the water in which they are held is made part of an [electrical] conducting circuit. If any such fish cannot survive when surrounded by water, what can we expect from such a small amount of water that it only moistens our clothes? I am certainly convinced that Mr. Franklin has made a mistake of one kind or another in this."

Bergman's Thunderstorm Lecture.

Bergman ended his lecture, and appended notes, as he often did, with a Latin quotation:

"Interea Physici studio non cedite
vestro,
Spes ut res ultro promoveatur adest.
Quam natura suis monstrat cultoribus
artem,
Fructibus eximiis accumulare sciet."

Which I translate:

Meanwhile our study of Physics never
ceases,
The search for knowledge is known to
progress of its own accord.
It is as if Nature wants to show its
secrets to the searchers,
So they learn to gather uncommon
fruits.

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