simple organization, approximating somewhat closely to that of the ovules of *Juniperus*, *Callitris*, and *Welwitschia*.

Some small seeds, which appear to be identical with the *Cardiocarpum tenellum* of Dawson, found in great numbers on slabs of shale by Mr. John Smith, of Kilwinning, in Ayrshire, are described. They were found in the upper Coal-measures near Stonehouse in Lanarkshire.

The last form noticed is a very curious winged seed from the uppermost Coal-measures of Ardwick, at Manchester, and which appears to have been a double seed, resembling in general form the samara of an ash. It belongs to Brongniart's genus *Polypterospermum*.

The fact that large numbers of seeds of unmistakable flowering plants exhibit very close resemblance to the *ovules* of Gymnospermous seeds is a very important one. Prof. Newberry has obtained such seeds in America; M. Grand-Eury has done the same thing in France; and it now appears that, though attention has but very recently been drawn to the existence of the smaller forms now described in the British Coal-measures, the discovery of a considerable variety has already rewarded the researches of the author and his auxiliary friends. There is no doubt that further research will materially increase that number. The question naturally arises, where are the Gymnospermous plants to which these seeds belonged? Finding the latter in the thin "upper-foot" coal-seam suggests that other remains of their parent stems should also be found there. The Dadoxylons are the only ones which exhibit any probability of such relationship. But these have chiefly been found in the marine Ganister bed, which underlies the upper-foot coal from which the majority of the seeds have been derived, indicating that the Dadoxylons grew apart from the Calamites and Lycopods abounding in the coal side by side with the seeds. Time alone can solve these problems, as well as others relating to the true homologies of some of the structures contained within these seeds.

V. "On Stratified Discharges.—II. Observations with a Revolving Mirror." By William Spottiswoode, M.A., Treas. R.S. Received May 3, 1876.

In a paper published in Poggendorff's 'Annalen,' Jubelband, p. 32, A. Wüllner has described a series of observations made, by means of a revolving mirror, upon the discharge of a large induction-coil through tubes containing ordinary atmospheric air at various degrees of pressure. When, as is generally the case with an induction-spark, the discharge occupies an appreciable interval of time, the image in the mirror appears spread out to a breadth proportional to the duration and to the velocity of rotation. The successive phases of the phenomena then appear, as usual, arranged in successive positions, and may be studied separately, even when too rapid to be disentangled by the unassisted eye.

Wüllner's observations appear to have been directed rather to the nature of the coil-discharge than to that of the stratifications; and some of his principal conclusions are accordingly of the following kind, viz. that at low pressures, *i. e.* down to 1 millim., when the discharge was stratified, the striæ showed an intermittence of intensity indicating either a pulsation within the duration of the main discharge or a breaking up of the main into a series of partial discharges. At greater pressures, *e. g.* at 26 millims., when almost all trace of stratification was lost, this breaking up into partial discharges (especially at the commencement) was distinctly perceptible. At yet greater pressures, *i. e.* from 40 millims. to 75 millims., a cloudy kind of stratification showed itself; but, excepting a bright flash at the outset, no appearance of partial discharge was visible. The observations, which were at first directed to capillary tubes, were extended to tubes of various diameters, and also included the effect of a magnet on the discharge.

For some time prior to the publication of the volume in question I had been engaged upon a series of experiments very similar in their general disposition, but with a somewhat different object in view, viz. the character and behaviour of the striæ; and of these, together with some recent additions, I now propose to offer a short account to the Society.

My general instrumental arrangements appear to have been similar to those of Wüllner; in fact they could hardly have been very different. The tubes were attached to the coil in the usual way, and a contact-breaker of the ordinary form with its own electromagnet was in the first instance used. By suitably adjusting the velocity of the mirror to the rapidity of the contact-breaker the image could be kept tolerably steady in the field of view. In order to obtain greater steadiness a special contact-breaker was next devised. This was mechanically connected with the spindle of the mirror, and so arranged as to break the current when the image was in the centre of the field of view. The only point in this part of the apparatus which requires special notice is the fact that this contact-breaker, like all others, should be placed in close proximity to the condenser of the coil, otherwise a great loss of light is sustained. For the last-mentioned form there was finally substituted a mercurial break (successfully arranged by my assistant, Mr. Ward), the plunger of which works on a cam attached to the axle of the mirror; so that the action of the contact-breaker is regulated by that of the mirror, instead of the reverse as in the former arrangement. With the broader tubes a slit was used; with the narrower this adjunct was less necessary; while with capillary tubes, such as are used for spectrum-analysis, it could be dispensed with altogether.

In experiments for comparing the unstratified statical discharge with the stratified at the same pressure of gas within the tube, and for observing the transition from one to the other, a Leyden jar and a spark

of air, the length of which could be regulated at pleasure, were introduced into the secondary circuit.

Striæ as observed by the eye have been divided into two classes, viz. the flake-like and the flocculent or cloudy. Of the former those produced in hydrogen-tubes may be taken as a type; of the latter those produced in carbonic-acid tubes. But upon examining some tubes especially selected for the purpose, it was found that, while to this apparent difference a real difference corresponds, a fundamental feature of the striæ underlying both was brought out.

The feature in question was this: that the striæ, at whatever points produced, appear to have generally during the period of their existence a motion along the tube in a direction from the negative towards the positive terminal. This motion, which I have called, for convenience, the proper motion of the striæ, is for given circumstances of tube and current generally uniform; and its variations in velocity are at all times confined within very narrow limits. The proper motion in this sense appertains, strictly speaking, to the flake-like striæ only. The apparent proper motion of the flocculent striæ is, on the contrary, variable not only in velocity, but also in direction; and on further examination it turns out that the flocculent striæ are themselves compounded of the flake-like, which latter I have on that account called elementary striæ.

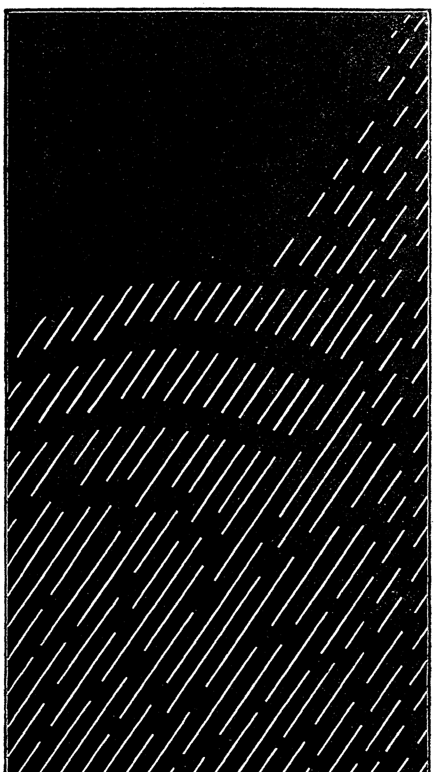
Elementary striæ are in general produced at regular intervals along the tube. The series extends from the positive terminal in the direction of the negative to a distance depending upon the actual circumstances of the tube and current. The length of the column, and consequently the number of the striæ, depends mainly upon the resistance of the tube, the duration of the entire current, and, to a certain extent, upon the amount of the battery-surface exposed; and in that sense upon the strength of the current. The velocity of the proper motion, other circumstances being the same, depends upon the number of cells employed; in other words, upon the electromotive force.

The appearances of the striæ, however, their essential features, and the conclusions which may be drawn from them will be better apprehended by means of sketches, even though imperfect, than by mere description; and I therefore subjoin a few examples.

Fig. 1 represents the appearance of (in the mirror) a carbonic-acid tube with the slit attached. This tube, viewed by the eye, shows flake-like fluttering striæ, with a slight tendency to flocculency near the head of the column. The commencement of the discharge is at the right hand, and the negative terminal at the top. The drawing fairly represents the appearance of the upper part or head of the column of striæ during one complete coil-discharge. When the battery-surface exposed is small, the whole consists of, first, three or four columns of striæ of decreasing length, and afterwards of an almost unbroken field of striæ. Each of the initial columns is perfectly stratified; and the same disposi-

tion of striæ prevails throughout the entire discharge. The striæ which fill the main part of the field present a proper motion nearly uniform, but slightly diminishing towards the end. These striæ are for the most part unbroken, but are occasionally interrupted at apparently irregular intervals. When the battery-surface is increased the elementary striæ are more broken, and near the head of the column the interruptions occur as in the figure. The separation of the earlier part of the discharged into striated columns divided by intervening rifts does not, with the exception of the first, extend far towards the positive terminal. Nevertheless, even as far as the positive terminal itself, there seems at times to be a fuller development of discharge than is subsequently maintained.

Fig. 1.



The first rift in the discharge, following the first outburst, is sometimes distinguishable even as far as the positive terminal; and perhaps in those cases indicates a real cessation of the discharge. This is corroborated by the fact that a similar interruption is then perceptible in the glow surrounding the negative terminal; but after this the negative

glow retains its unbroken character throughout the entire period of the discharge.

The stratified columns with their intervening rifts are sometimes reproduced towards the close of the discharge; but this appears to take place only when the battery is in an unusual condition of energy, and disappears when, as in the bichromate battery, polarization of the plates rapidly takes place. On these occasions especially, but also at other times, traces may be seen of the faint lines of light connecting the positive with the negative parts of the discharge mentioned by Wüllner in the paper quoted above.

Other tubes, when viewed by the eye, show flaky striæ more or less difficult to distinguish from one another. Observed in the mirror, they show much the same phenomena as the tube figured above, except that the striæ are rather more crowded together and slightly more broken. This is the case especially with ammonia-tubes, in some of which the striæ are undistinguishable by the eye, and which accordingly give the impression of an unstratified column of light.

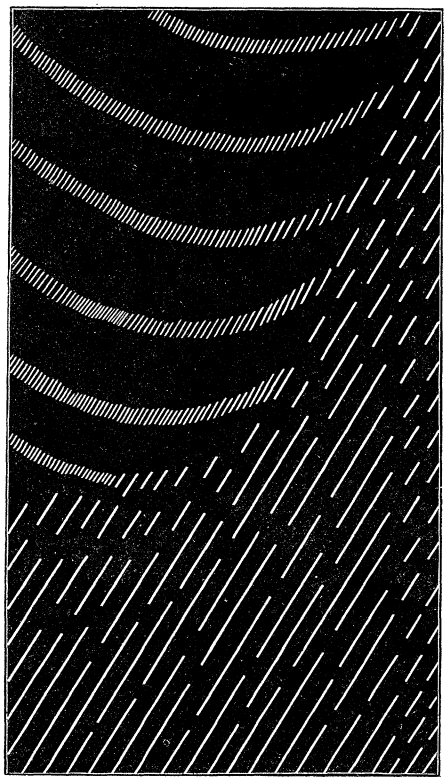
Fig. 2 represents the appearance in the mirror of another carbonic-acid tube with a current similar to that used in the former case. Viewed by the eye it shows flocculent striæ, each having a contour sharply defined towards the negative terminal, loosely defined towards the positive. The following description of the phenomena, taken from my earlier notes, may now be regarded as a description of the apparent proper motion of the flocculent as distinguished from the elementary striæ:—"The discharge opens with a considerable rush, indicated by the bright line at the commencement. There is no other indication of partial discharges. Proper motion at first towards the negative, afterwards towards the positive terminal. In this, as in other tubes giving striæ of this kind, ripples may be observed on the curve of proper motion."

So far my older notes; but on closer examination, and when the battery-surface exposed is sufficiently reduced, the entire field is seen to be traversed by elementary striæ having a normal proper motion. When the battery-surface is gradually increased, the elementary striæ, especially near the head of the column, have their duration shortened so as to leave dark intervals at regular stages in the column. These successive short-lived elementary striæ form a series of diagonal lines, each series of which traces a sketch of a flocculent stria. As the surface is still further increased these diagonal lines appear more and more crowded together, until at last they blend into unbroken flocculent striæ.

This compound nature and mode of formation may be taken as a general characteristic of the flocculent striæ. In some tubes it is more easily brought out, in others only with greater difficulty. In some it can hardly be verified experimentally without a loss of light so great as to mask the phenomenon. The apparent proper motion of the flocculent striæ depends, as is easily seen, upon the position at which the elemen-

tary striæ are replaced. If they are replaced in the positions which their predecessors held, the flocculent striæ will appear straight in the mirror; if they are replaced successively nearer the positive terminal, the apparent proper motion will be in the normal direction; if nearer the negative, it will be reversed.

Fig. 2.



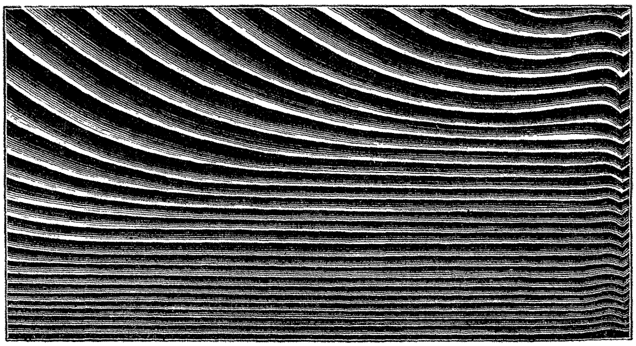
An ether-tube examined in the same way showed nearly the same features as the last. The elementary striæ were, however, not so easily separable; and the flocculent striæ were formed as usual at an earlier stage near the head of the column than near the foot of it.

In another carbonic-acid tube the proper motion of the flocculent striæ was coincident in direction with that of the elementary; and the latter were consequently more difficult to disentangle. One point in this tube was particularly noticeable, viz. that as the column of flocculent striæ retreated, so did the negative glow advance. The two remained throughout the entire discharge the same distance apart.

Fig. 3 represents the discharge in a hydrogen-tube of conical form,

the diameter of which varied from capillary size to $\frac{1}{2}$ inch, the capillary end being at the bottom. The positive terminal is at the top. The principal interest of this tube consists in showing the influence of diameter upon the velocity of proper motion. The wider the tube the

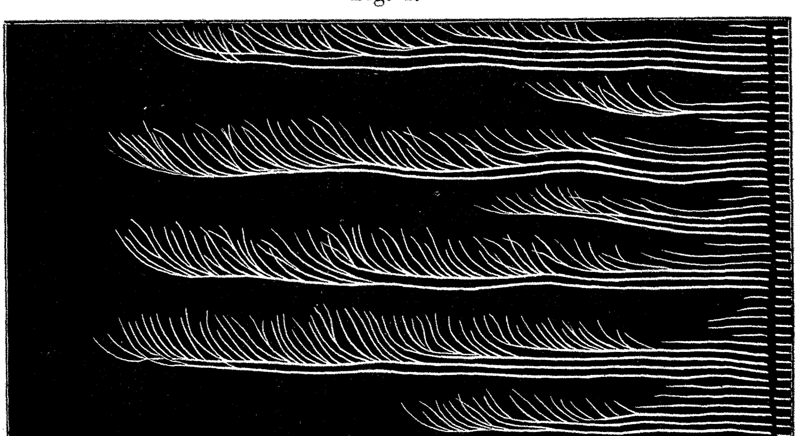
Fig. 3.



freer, it seems, the striæ are to move. The same fact may be observed by comparing tubes differing in diameter, but in other respects the same; but the conical tube brings out the fact in the most striking manner.

Fig. 4 represents a chloroform-tube, in which a piece of cotton-wool had been inserted with a view of ascertaining whether any motion would be communicated to it by the current. This proved to be the case; but I do not attempt here to describe the phenomenon. To the unassisted eye the discharge was extremely brilliant; it passed in a column not quite straight, but in a writhing snake-like curve, with flaky striæ at

Fig. 4.



intervals through its length. When viewed in the mirror the striæ were seen to spread themselves out with slight, but irregular, proper motion. With an increased battery-surface, or with a greater number of cells, but more notably with the latter, not only were the striæ lengthened, but from several of the long elementary striæ shorter ones were thrown out nearly at right angles to the former. These were of short duration, and had great proper motion. The general appearance of these compound striæ was that of branches of fir trees, the twigs of which represented the permanent striæ, and the leaves the secondary.

Beside these, a large (Geissler's "hydrocarbon") tube was examined with a magnet the pole of which was placed near the head of the column; and in order to trace more in detail the effect of the magnet, its strength was varied by raising or lowering the battery-plates. The general character of the discharge without the magnet was very similar to that represented in fig. 1. On slightly lowering the plates of the magnet-battery the discharge spread itself over a greater breadth than before. At the same time the elementary striæ, which had for the most part been continuous, were now broken up into short lengths, presenting the first features of flocculent striæ. On further lowering the plates these flocculent striæ became more and more developed until the whole field in the neighbourhood of the magnetic pole became filled with such striæ. It is well known that one effect of the magnetic field is to bring out striæ in portions of tubes where no striæ were visible before, and also that the striæ so brought out present a flocculent appearance; but the revolving mirror shows this fact in a more decisive manner. Another effect of the magnetic field is to drive the discharge to one side of the tube in accordance with Ampère's law—in other words, to constrict the discharge. In narrower tubes than the one here described, the constriction goes so far as to imitate the appearance of a capillary tube; and this effect is borne out by the revolving mirror. The intensification of the discharge and its concomitant phenomena within the range of the magnetic field are in accordance with the experiment of Faraday, wherein he showed the increased loudness of the report perceptible on breaking a current in between the poles of a magnet.

In a carbonic-acid tube (Gassiot's No. 454) I have succeeded in starting with a very weak current, capable of producing only elementary striæ, and thence passing to the production of flocculent striæ, either by strengthening the battery-current, or by inducing upon the existing current the action of a magnetic field. The identification of the results of these two independent processes, especially when combined with the comparison made above of the effect of magnetism with that of narrowing the tube, can hardly fail to have some important signification in the ultimate theory of the striæ.

Besides the tubes above mentioned many others were tried; but these will probably suffice for the present purpose.

The following are some of the general conclusions to which the foregoing experiments seem to lead :—

I. The thin flake-like striæ, when sharp and distinct in their appearance, either are short-lived or have very slow proper motion, or both.[a]

II. The apparent irregularity in the distribution of such striæ, during even a single discharge of the coil, is due, not to any actual irregularity in their arrangement, but to their unequal duration and to the various periods at which they are renewed. These striæ are, in fact, arranged at regular intervals throughout the entire column. The fluttering appearance usually noticeable is occasioned by slight variations in position of the elementary striæ at successive discharges of the coil. With a view to divesting the coil-discharge of this irregular character, as well as for other purposes, I devised two different forms of contact-breakers (one of which is described in the Royal Society's 'Proceedings,' vol. xxiii. p. 455); but I postpone a description of the second, as well as of the experiments arising from its use, to another occasion.

III. The proper motion of the elementary striæ is that which appertains to them during a single discharge of the coil. This appears to be generally directed from the positive towards the negative terminal. Its velocity varies generally within very narrow limits. It is greater the greater the number of coils employed, or the greater the electromotive force of the current. In some tubes it may be seen to diminish towards the close of the discharge; and even in rare instances alternately to increase and to diminish during a single discharge.

IV. Flocculent striæ, such as are usually seen in carbonic-acid tubes, are a compound phenomenon. They are due to a succession of short-lived elementary striæ, which are regularly renewed. The positions at which they are renewed determine the apparent proper motion of the elementary striæ. If they are constantly renewed at the same positions in the tube, the flocculent striæ will appear to have no proper motion and to remain steady. If they are renewed at positions nearer and nearer to the positive terminal, the proper motion will be the same as that of the elementary striæ; if they are renewed at positions further and further from the positive terminal, the proper motion will be reversed.

V. The velocity of proper motion varies, other circumstances being the same, with the diameter of the tube. This was notably exemplified in the conical tube. In tubes constructed for spectrum-analysis the capillary part shows very slight, while the more open parts often show considerable proper motion.

VI. Speaking generally, the discharge lasts longer in narrow than in wide tubes. In spectrum-tubes the capillary part gives in the mirror an image extending far beyond that due to the wider parts.

VII. The coil-discharge appears, in the earlier part of its development at least, to be subject to great fluctuations in extent. In all cases there

is a strong outburst at first. This, although sometimes appearing as a bright line, is always, I believe, really stratified. Immediately after this there follows a very rapid shortening of the column. The extent of this shortening varies with circumstances; but when, as is often the case, it reaches far down towards the positive terminal, a corresponding diminution of intensity is perceptible in the negative glow. The column of striæ, after rising again, is often subject to similar fluctuations. These, which are sometimes four or five in number, are successively of less and less extent, and reach only a short distance down the column or striæ. The rifts due to these fluctuations then disappear, and the striæ either continue without interruption, or follow broken at irregular intervals, until the close of the discharge.

VIII. The effect of the proper motion, taken by itself, is to shorten the column of striæ. But, as we have seen, the striæ are in many cases renewed from time to time. In regard to this point, the head of the column presents the most instructive features. After the cessation of these rifts, the general appearance of the field is that of a series of diagonal lines commencing at successive points which form the bounding limit of the column at successive instants of time. If the points are situated in a horizontal line, the striæ are renewed at regular intervals at the same place; and the length of the column is maintained by a periodic renewal of striæ, a new one appearing at the head of the column as soon as its predecessor has passed over one dark interval. If the boundary of the illuminated field rises, the length of the column increases; if it descends, the column shortens. In every case, however, the growth of the column takes place by regular and successive steps, and not irregularly. The intervals of the new striæ from one another and from the old ones are the same as those of the old ones from one another.

IX. The principal influence of a change in the electromotive force appears to consist in altering the velocity of proper motion. A change in the amount of battery-surface exposed produces a corresponding change in the duration of the entire discharge, as well as apparently in the development of some of the minor details of the striæ.

X. When the proper motion of the elementary striæ exceeds a certain amount, the striæ appear to the eye to be blended into one solid column of light, and all trace of stratification is lost. When this is the case the mirror will often disentangle the individual striæ. But there are, as might well be expected, cases in which even the mirror is of no avail, but in which we may still suppose that stratification exists. A variety of experiments have led me to think that the separation of the discharge into two parts, viz. the column of light extending from the positive terminal, and the glow around the negative, with a dark space intervening, may be a test of stratified discharge; but I cannot affirm any thing certainly on this point.

Fig. 1.

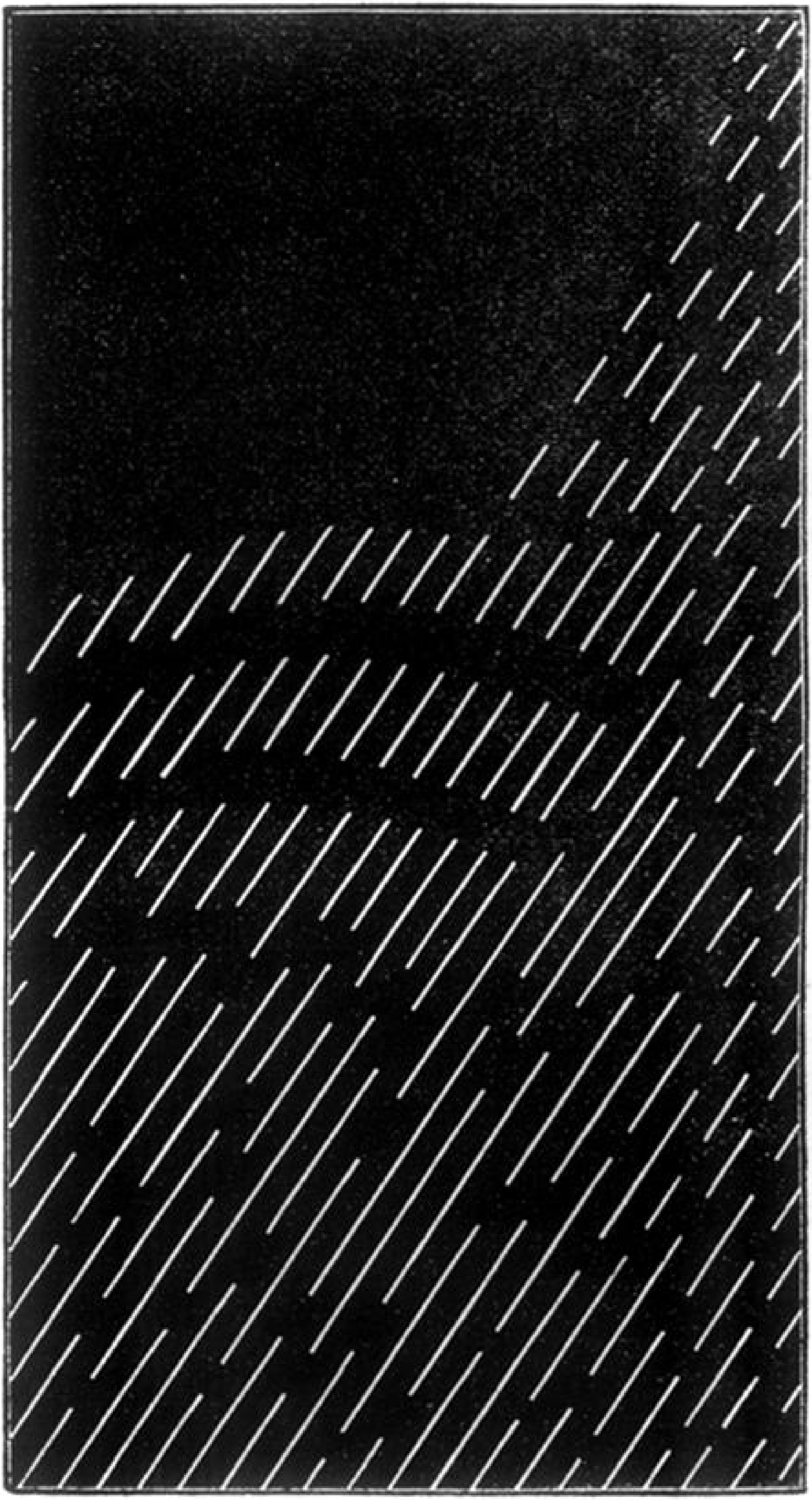


Fig. 2.

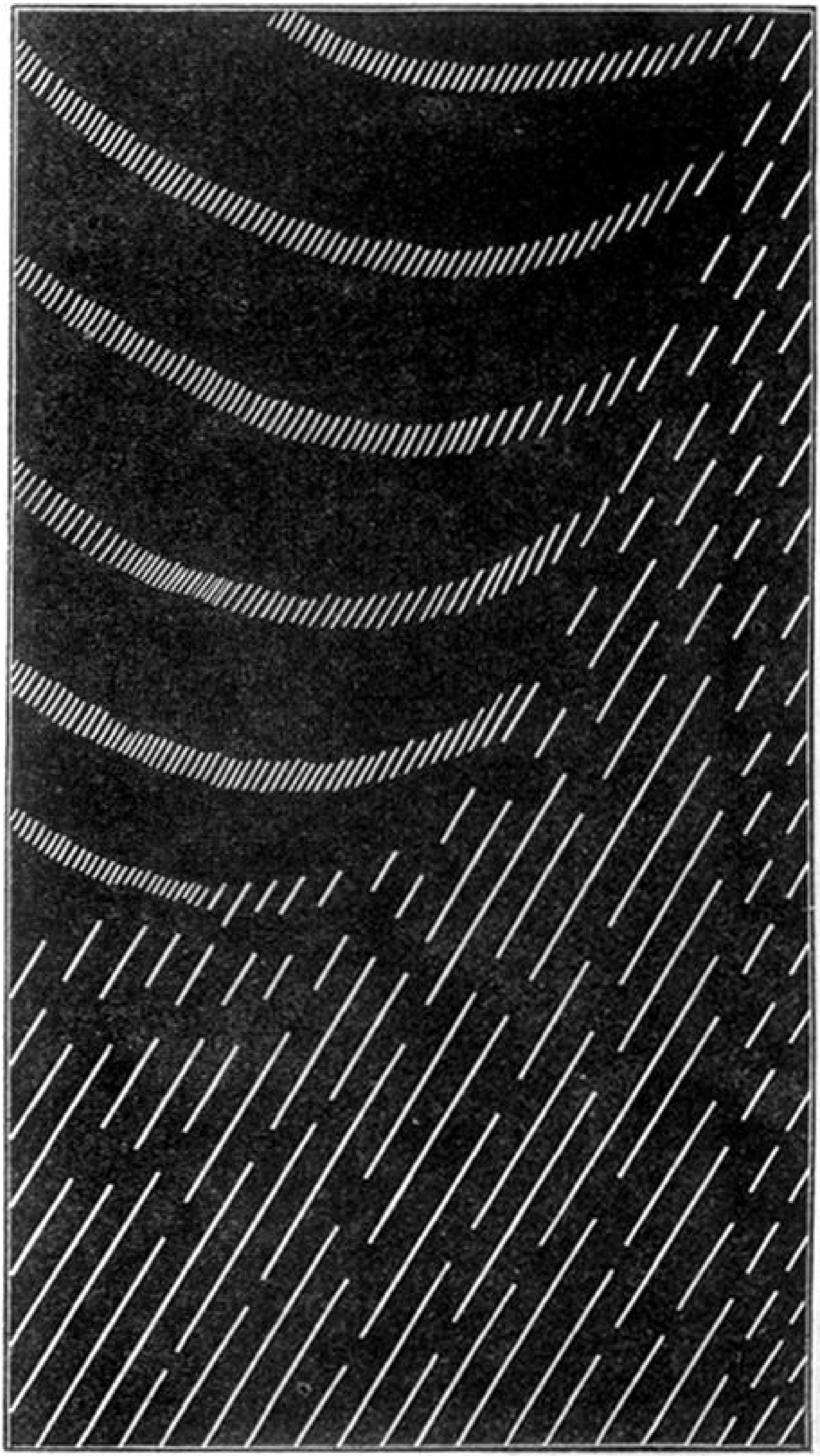


Fig. 3.

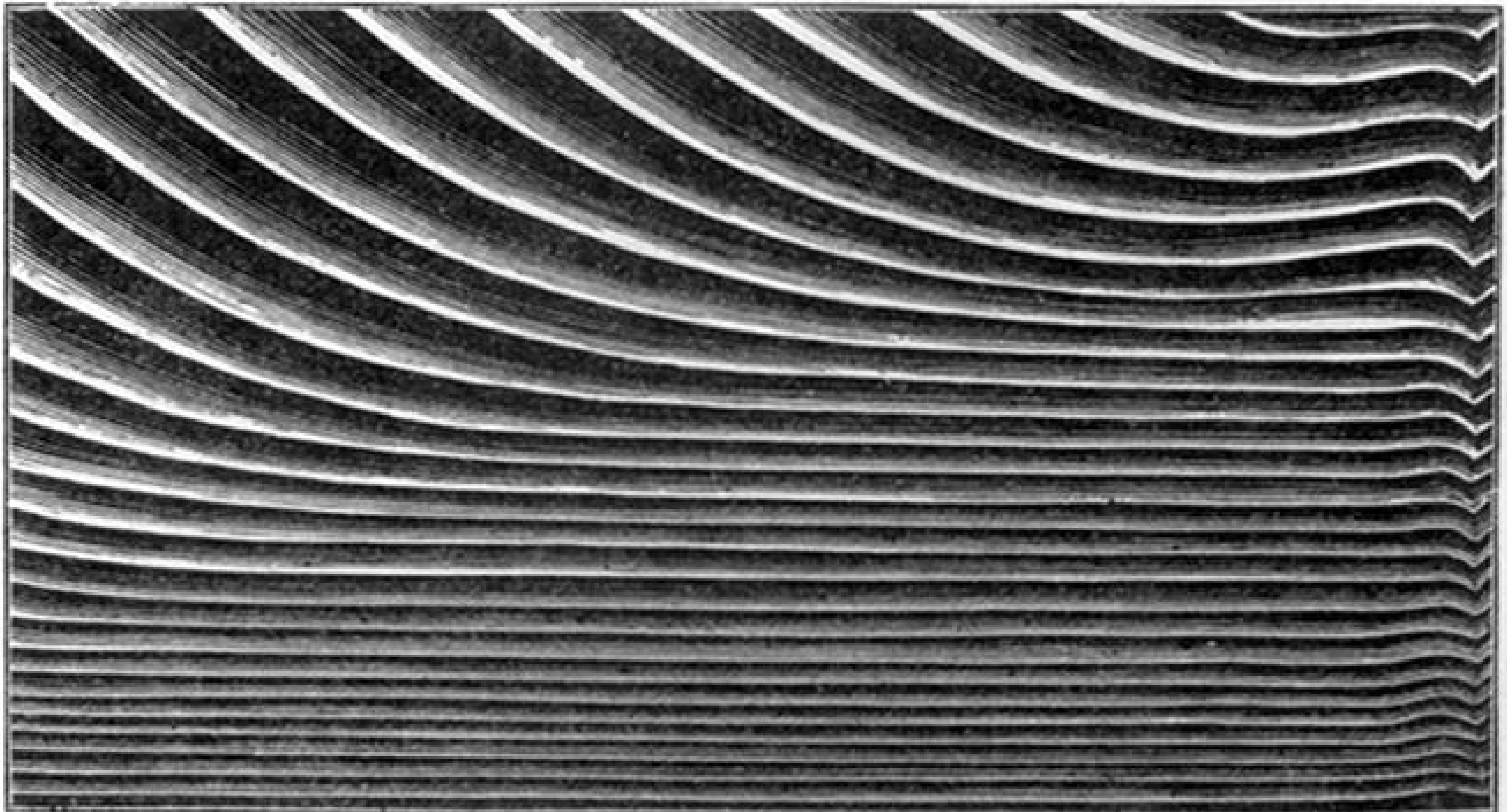


Fig. 4.