A NEW VISUAL ILLUSION OF DIRECTION.

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I.

In all the hitherto published visual illusions of direction, with the exception of the Chequer-board or Münsterberg illusion, the illusory lines or bands are definitely continuous, uninterrupted in character, of black or of white, on a contrasting background. In the illusion of direction here described each illusory band consists of a series of visibly discrete similar parts, all inclined at the same small angle to the line of direction of the series to which they belong. Such visibly discrete similar parts may be conveniently termed 'units of direction.'

Where the illusory band consists of alternating black and white 'units of direction,' it may be conveniently regarded as representing a cord consisting of two strands, black and white, twisted together. This arrangement will, in the descriptions, be referred to as 'the twisted cord.' A twisted cord laid upon a grey or coloured background of intermediate luminosity will apparently deviate from its actual line of direction at an inclination corresponding in trend (but at a smaller angular degree) to the inclination of the units of direction. This illusion is much increased in degree when the twisted cord is laid upon a chequer-work background of squares of white, black, and an intermediately luminous grey or colour in such a way that it bisects diagonally each member of a series of black and white squares, its black and white units bisecting respectively white and black squares (their contrasts) at a small angle with the diagonal line of the square as seen in No. 14, Fig. 15. In such a figure each unit of direction is now, in effect, lengthened by the addition of a triangular area of the same luminosity at each of its ends (No. 14, Fig. 15). These triangular areas are derived or borrowed from the neighbouring squares belonging to the series on which the twisted cord lies, and they lie on opposite sides of the twisted cord. This form of unit of direction may be conveniently (as distinguished from the 'simple unit of direction') termed a 'compound unit of direction,' its middle or rod-shaped portion corresponding to the twisted cord and the triangular end portions corresponding to black or white squares of the chequer-work background. This form of the illusion, in which there is a visual fusion of the twisted cord with a chequer-work background, may be termed the 'twisted cord on chequer-work background' illusion.

In some of the figures the twisted cord must be regarded as fixed at certain points, and, starting from these points, to be twisted in an opposite direction.

In Fig. 2 and in the outer and inner pair of curves in Fig. 6 the strands are not twisted but lie uninterrupted, side by side, their marginal dividing line being the diagonal line of a black or white square. This arrangement, which may be named the 'untwisted strands on chequer-work background,' gives a figure which contains a slight illusory element contrasting with the much more definite illusion of the twisted cord.

II. *The properties of Fig.* 1.

In the following six sections the main properties of Fig. 1, representing the word LIFE, are described. The letters, it should be remarked, are assumed to be seven inches in height. The writer's vision is normal.

(1) The illusion persists through the entire range of visibility of the letters both in relation to the size of the image and to the amount of illumination. In bright diffuse daylight illumination the letters are visible, as such, up to a distance of about 45 feet. Beyond this point the chequered background is vaguely streakily smudged in the areas occupied by the letters. As the figure diminishes in size the letters correspondingly lose their quasi-continuous outline character and are resolved into overlapping black and white fragments (the 'units').

When Fig. 2, similarly constructed, but with letters of really continuous outline ('untwisted strands on chequer-work background') is examined in the same way, the letters remain rectangular and erect under all conditions, but become slightly sinuous or wavy at a distance of 12 to 15 feet. This sinuosity increases with the decrease in size of the image until finally at about 45 feet the letters are represented by a smudging of the chequered background.

The resolution into overlapping units in Fig. 1 and the change from straightness to sinuosity in Fig. 2 seem to be identical visual phenomena. Under the conditions of size and distance stated—in Fig. 1 some point in each triangular area forming the end of a compound unit of direction becomes the definite visual terminal of the unit, and in Fig. 2 the apex of each triangular area attached to the black and white strands becomes the visual terminal of short curves which form a black series and a white series, side by side, the middle points of the curves lying on the marginal dividing line of the black and white strands.

(2) If Fig. 1 be turned through a right angle in the plane of the paper the illusion is sensibly increased for the long limits of the letters, the apparent angular inclination being greater in the horizontal than in the vertical positions.

(3) The illusion is undiminished in degree as perceived during a single flash illumination of a duration of $\frac{1}{8}$ second.

(4) On steady fixation the illusion persists.

If a point be fixated midway between two of the letters, at a distance of eight inches to three feet, the outlined letters and the chequer-work background sensibly compete or alternate with each other in consciousness, the rod-shaped middle portions of the compound units of direction being annulled or swamped, as it were, at time intervals, by the dominance of the sweeping dark and light broad diagonal bands formed by the visual union of the black and white squares with the grey squares. In the negative after-image this alternation can be distinctly perceived, the illusion of direction being present as the letters periodically appear.

(5) If letters outlined by the 'untwisted strands' as in Fig. 2 be rotated round their central points on the chequer-work background so as to correspond in actual angular inclinations with the apparent angular inclinations in Fig. 1, and viewed at a distance of about six feet, this angle is found to be slightly less than the angular inclination of the units of direction.

(6) If Fig. 1 be binocularly combined with a figure of similar size and structure in which there are reversed angular inclinations, unit for unit, the letters directly regarded become erect, and a slight amount of ambiguous relief is obtained. The units of opposing angular inclinations in the vertical limbs will, when so combined, result in units which have no lateral inclination, but seemed to be turned about horizontal axes lying in the plane of the paper. The units in the horizontal series, in combination, are crossed. The letters thus retain their continuity, but appear to be slightly disengaged from the background.

III. *A triple series of variants of Fig.* 1.

By a step by step removal of similar geometrical parts from Fig. 1 a triple series of figures can be obtained of importance for a study of the illusion.

SERIES I. A white background series.

- 1[a]. Removal of all the grey squares.
- 1[b]. Removal of all the black squares with the exception of those forming parts of the black units.
- 1[c]. Removal of the lateral angular parts of these black squares.
- 1[d]. Shortening of the black units so that they no longer overlap but are separated by intervals of the same length as themselves.
- 1[e]. These intervals are filled by similar black units of the same

angular inclination so that the units in a series touch each other at angular points.

SERIES II. A corresponding black background series (not illustrated).

SERIES III. A grey background series.

1^{3a}. Removal of all the black and white squares with the exception of those forming parts of the black and white units.

1^{3b}. Removal of the lateral angular parts of the squares of all the units.

1^{3c}. Shortening of the units so that they no longer overlap but touch one another at angular points.

In Series I the illusion diminishes in sharpness up to 1^{e}. Here (still assuming the letters to be seven inches long) the illusion is present up to a distance of about 15 inches only. Beyond this distance a change of the nature of *confluent union* takes place, a core of blackness, as it were, running through each series of units and causing a definite visual union, so that the letters are now erect and rectangular although of distinctly ratchet-like outline.

The same descriptions may be applied to Series II (the black background series). In Series III (the grey background series) the illusion diminishes in sharpness and brightness up to 1^{3c}. In 1^{3a} sharpness and brightness are still present in the letters directly regarded. In 1^{3b} sharpness is lost. In 1^{3c} both sharpness and brightness are lost. In 1^{3a} although *geometrically* the figure consists of black and white adjacent areas with triangular ends lying on a grey background, *visually* it consists of the 'twisted cord' lying on a fragment of chequer-work background.

In Fig. 1^{3b} the brightness is due to each unit being still largely enclosed between two contrasting units.

If Fig. 1^{a} and a corresponding figure on a black background be compared with Fig. 1, it will be found that the letters in Fig. 1 (which contains equal areas of black and white) possess a sharp clearness of outline absent in the two other figures (in which there is a large excess of either black or white).

A similar triple series of variants of Fig. 2 may be obtained by the method described above, and will support the explanation offered as to the relation of the sinuosity in Fig. 2 to the resolution into units in Fig. 1.

IV. *Two coloured variants of Fig.* 1 (*not illustrated*).

Coloured variant A. In Fig. 1—

If for black squares be substituted squares of saturated red,
„ grey „ „ „ „ „ light red,
„ white simple units „ units „ greenish-blue,

a figure is obtained which presents the illusion in a diminished degree. At a distance of about 15 inches and beyond, when viewed through a transparent red medium corresponding to the red in the figure, and sufficiently intense to almost obliterate the squares, the illusion disappears. The figure, under these conditions, in fact, corresponds to Fig. 1^e. Confluent union of the now almost equally dark units on a now almost uniformly light background has taken place. Viewed, at a distance, through a transparent medium of corresponding greenish-blue the illusion is markedly increased; the figure now corresponding to Fig. 1. Increase of the illusion also takes place if the figure be viewed at any distance with very feeble illumination when the eyes have become dark-adapted. This is explained by the fact that the retinal response to stimulation by colours of very low luminosity (attributed to the retinal rods) is much less for red than for the other colours. The reds and greenish-blues become therefore relatively darker and brighter. There is now increased contrast.

Coloured variant B. If in Fig. 1—

For black squares be substituted squares of saturated greenish-blue,
„ grey „ „ „ „ light „
„ white simple units „ units „ red,

a figure is obtained in which the illusion is increased by being viewed at any distance through a red medium. This is due to the now increased contrast of the dark and light units and the dark and light squares. The illusion is abolished by being viewed at about 15 inches and beyond through a greenish-blue medium. It is also abolished by dark-adaption inspection at the same distance. In the two latter cases the abolition of the illusion is due to confluent union of the now almost equally dark units on a now almost uniformly light background.

When the coloured variant *A* is illuminated by a flash lasting $\frac{1}{8}$—$\frac{1}{2}$ second, the direct image presents the illusion in a degree corresponding to that due to ordinary inspection and is followed by a brief after-sensation by which the illusion is perceived exaggerated.

When the coloured variant *B* is similarly illuminated at a distance of three feet and beyond, the direct image presents the illusion in a degree corresponding to that due to ordinary inspection, and is followed by a brief after-sensation by which the illusion is abolished, the letters appearing black and erect.

In fact, the after-sensations of such brief illuminations of the coloured variants *A* and *B*, correspond exactly to the appearances of these figures when seen in very feeble illumination by the dark-adapted eyes[1].

V. *Construction of the circular figures.*

In the construction of the circular figures a circular area is divided by radial lines into a certain number of equal sectors (*e.g.* 32 in Fig. 3, 48 in Fig. 5). A series of concentric circles are then described at such intervals that the quadrangular divisions obtained have each three equal sides, the outer circumferential side and the two radial sides, and one side (the inner circumferential) which is slightly shorter. These quadrangular areas are thus approximate squares and on being bisected diagonally in both directions give a new group of approximate squares which is used as the basis of the background of the illusory figure to be produced. The two sets of diagonals of the second group of approximate squares are the original radial and circular lines, and on these lines rest the 'units of direction.' The 'units of direction' all bear the same relation in size to the approximate squares on which they lie, so that in the completed figure the members of each radial series of similar

[1] When these observations in connexion with brief illumination of the coloured variants were made they immediately recalled to the writer a puzzling colour experiment of three years before. A screen photograph 'half tone' print ($\frac{1}{6}$ inch square) of a man's face was enlarged so that the black and white areas when of equal size were $\frac{1}{6}$ inch square. An exact copy of this was made, substituting red for black and greenish-blue for white, the colours being saturated and apparently of equal luminosity. (This figure, potentially both a positive and negative portrait, was used for some observations in connexion with retinal rivalry, a positive portrait being produced for one eye and a negative portrait for the other by the interposition of corresponding red and green-blue media.) The writer was astonished to find that the after-sensation of a brief illumination (the duration of which was not then timed), the figure being placed at 1 to 2 feet from the eyes, was usually a more or less definite positive portrait. He now finds that in the after-sensations of a brief illumination ($\frac{1}{3}$—$\frac{1}{2}$ second) of a series of saturated colour areas, arranged in spectral order, the greenish-blue appears to be the most luminous and the red the least luminous. The other colour areas appear intermediate in luminosity, orange-yellow and blue-violet being of nearly equal luminosity. These luminosity relationships correspond to those perceived in very feeble illumination of the same coloured surface by the dark-adapted eyes.

geometrical parts diminish in size centripetally by geometrical progression, and the members of any circular series are of equal size.

The chequer-work background is composed of a double series of dark and light broad spiral bands running in counter directions, and formed by the visual union of the black and white squares with the grey squares. The units of any one circular series all correspond to the same circle in one of two ways—either the centre of area of a unit corresponds to the centre of a black or white square; or, the marginal dividing line of two 'units' corresponds at its central part to the diagonal line of a black or white square, that is, to part of the actual circular curve. In Figs. 4 to 7 the curves are arranged in pairs; there being a distance equal to the sum of the radial diagonals of two grey squares between the pairs. The curves in each pair have an identical distribution of the angular inclinations of the units; the units of neighbouring pairs of curves being opposed in angular inclination.

As in Fig. 1 the length of each unit is approximately equal to the sum of the diagonals of three squares, except where a change in the angular inclination takes place. Here either the outer or the inner unit is approximately equal to the sum of five diagonals, as in Fig. 5.

In Fig. 3 the angular inclination of the units is the same throughout.

In Fig. 4 the units in each pair of curves are inclined in an opposite direction to that of the units of a neighbouring pair.

In each curve of Figs. 5 and 9 there are four equidistant squares on which the centre part of the units lie side by side so that their marginal dividing line coincides with the diagonal line of a square, that is, with the circular curve. Starting from the angular points of each of these four squares the units are inclined in opposite directions.

In Fig. 5 the distribution of the angular inclinations of the units is such that the apparent long diameter of each pair of curves is at right angles to the apparent long diameter of a neighbouring pair.

In Fig. 8 on each curve there are eight equidistant squares starting from the angles of which the units are inclined in opposite directions.

At the four angular points of the 'squared' circles the central point of the marginal dividing line of the units is very slightly outside the circular line.

In Fig. 9, where there is no arrangement of the curves in pairs, the distribution of the angular inclinations of the units is such that the apparent long diameter of each curve forms an angle of 45° with the apparent long diameter of each neighbouring curve.

On ordinary visual examination of this figure, with the exception of the outer curve, it is extremely difficult to isolate individual curves. Neither the actual nor the apparent nature of the curves can be definitely perceived. The general impression is that of an entanglement of curves, or of a single very irregular curve. On steady fixation, however, of some point in the figure, preferably the central point, the curves tend to isolate themselves in a varying sequence, illusory elliptiform curves, whose long diameters have apparently different angular inclinations, succeeding one another in consciousness, the four angular directions being easily discriminated.

In Fig. 6 the two middle pairs of curves correspond to the curves in Fig. 5. The outer and inner pairs of curves are of the 'untwisted strands' type. There is in them no illusion as to the geometrical nature of the curves as a whole; but sinuosity or waviness is obtained under the conditions described for Fig. 2.

In Fig. 7, starting from each end of the horizontal diameter of each curve, the angular inclination of the units is reversed.

In Fig. 10, the background of which is similar to that of the other figures of a circular type, an illusion is produced as to the direction of the actually radial 'twisted cords.' There is an opposite angular inclination of the units in neighbouring 'twisted cords,' and a corresponding apparent inclination of each cord.

The 32 radii, instead of appearing to reach the centre of the figure, appear to meet, in pairs, on 16 equidistant points on the circumference of a circle described at some indefinite distance from that centre.

An elliptical figure.

In Fig. 11 a concentric series of (geometrically) similar ellipses is treated in the same fashion as the circular curves. The short diameters are to the long diameters as 7 to 8. Starting from the vertical angles of the squares whose horizontal diagonals correspond to the long diameters of the ellipses, the angular inclination of the units is outwards from the elliptical curves. The marginal dividing lines of the central parts of the units which correspond to the ends of the long and short diameters of the ellipses coincide with the elliptical curves. The result of this treatment of the elliptical curves is that from without inwards the curves become apparently more and more circular in character; the inner curves simulating ellipses having long diameters at right angles to the long diameters of the outer curves. If the figure be rotated through half a right angle in the plane of the paper, the apparent gradations are probably better appreciated. Viewing the figure with any angle of rotation the *identification* of the curve which appears to be the normal circle is impossible.

VI. *General Properties of the circular figures.*

The properties of Fig. 1 described in six short sections on pp. 309 f. belong also to the group of figures of circular character (Figs. 3 to 11), and may be considered in the same order, noting a few new characters due to the geometrical nature of the figures.

(1) *Changes in character of the illusion, due to changes in the size of the image.* Examining each figure from without inwards, the tendency to resolution into the overlapping black and white units increases with the decrease in size of the parts. The inner curves, therefore, or the inner parts of the radial bands (Fig. 10) appear to be more broken up than the outer curves or than the outer parts of the radial bands. This is most apparent where the curves are separated into pairs, which contrast by their opposite angular inclinations with neighbouring pairs (Figs. 4, 5, 6, 7).

Where there is parallelism in the inclinations of the units throughout, as in Figs. 3, 8, 11, the resolution into units brings about *a confusion of identity* in connexion with the inner curves, that is, any one of these smaller curves is easily confused with its outer or inner neighbour. This confusion of identity results in an exaggeration of the illusion, so that the central curves of these figures show an apparently greater departure from the actual geometrical form than the outer curves.

If Fig. 3 or Fig. 11 be examined at gradually increasing distances the inner curves gradually cease to be visible, the visible curves showing a greater degree of the illusion as they approach invisibility. If the centre of Fig. 3 be compared with the centre of Fig. 4, at corresponding distances, the central pair of curves of Fig. 4 appear as a double whorl of overlapping units, while the corresponding central part of Fig. 3 simulates a continuous curve.

The apparent incurvation and excurvation opposite the ends of the evidently short diameters and long diameters respectively of the illusory elliptiform curves (Figs. 5, 6) increase with the diminution in the size of the curves. This phenomenon, in fact, is correlated with the tendency to resolution into units, and, in explanation, the theory may be applied which is offered above as to the sinuosity in Fig. 2.

(2) *Effects of angular position of figure.* If illusory elliptiform curves of equal size be compared, the illusion as to the relative lengths of the apparent long and short diameters will be found to be slightly greater when the apparent long diameters are in the horizontal position.

(3) *Images of very brief duration.* In all the figures the illusion is distinctly present in images of very brief duration ($\frac{1}{8}$—$\frac{1}{2}$ second).

(4) *Effects of steady fixation.* On steady fixation the illusion persists in all the figures; there being a distinct alternation, at time intervals (1 to 2 seconds), of the curved or radial figures with the double spiral background.

In Fig. 9, as already described, the curves tend to isolate themselves in a varying sequence.

In Fig. 3 the apparently open curve becomes broken up into its constituent closed circular curves. These, at intervals, are perceived as distinctly isolated circles having a spiral character or tendency.

In the negative after image of all the figures the alternating changes described can be distinctly perceived.

(5) The figures of circular type have not been examined by the method described in Section 5 of the description of Fig. 1.

(6) *Binocular Combination.* If any one of the figures of a circular type (excluding Fig. 11) be binocularly combined with a figure of equal size and similar structure, but having opposed angular inclinations, unit for unit, the result is the perception of a concentric series of perfect circles, or a series of normal radial bands (Fig. 10); there being an ambiguous relief of the circles or radii in relation to the background,—an impression of disengagement.

If Fig. 6 be combined with the same figure turned through a right angle in the plane of the paper, the effect is that of four pairs of concentric circles, the outer and inner pairs being level with the background, the two middle pairs being disengaged from the background.

The variants, coloured and uncoloured, described for Fig. 1, may be made for the figures of circular type and show corresponding phenomena.

VII. *An illusory figure examined in relation to a corresponding non-illusory figure.*

The visual geometrical paradox present in most of the 'twisted cord' figures is only fully appreciated by a comparison of the illusory figure with a figure drawn to imitate it. In Fig. 5[a] an attempt has been made to reproduce the illusory curves in Fig. 5. Each space between the two pairs of curves in Fig. 5[a] narrows and broadens as the pairs of curves mutually approach or recede, so that their nearest and farthest distances from each other are in the ratio of 1 to 3. In Fig. 5 the corresponding spaces are, of course, of uniform breadth throughout, but in an ordinary examination of Fig. 5, with free undirected eye-movements, this is not perceived. If, however, the vision be slowly swept round an interspace, closely following a circular line of intermediate black and white squares, although this uniform breadth can be now appreciated, the curves are still perceived as elliptiform pairs with long diameters alternating in vertical and horizontal directions.

VIII. *The Münsterberg or chequer-board illusion as related to the 'twisted cord on chequer-work background' illusion.*

The Münsterberg illusion may be regarded as an illusion of the 'unit of direction' type.

In Figs. 12, 13, 14, a gradual geometrical transition series, extending from the one illusion to the other, is given; and in Fig. 15, are shown in numbered divisions corresponding to each member of the series:

(1) The type of each compound unit of direction.

(2) The type of its apposition to the neighbouring contrasting unit.

(In Nos. 7 to 14 of Fig. 15, the black and white squares completing the chequer-work background are, for the sake of clearness, omitted.)

In the text-books the Münsterberg illusion is usually represented with either the black units or the white units incomplete; that is, either with thin black bands separating the white squares from each other, or with thin white bands separating the black squares. Each band represents the middle portion of a unit. The illusion is distinctly increased in degree when both black bands and white bands are present, and in such an arrangement when a broad band of grey is laid alongside the squares on either side a series of units is obtained, alternating black and white, of identical shape and size, on a background of intermediate luminosity.

In Nos. 2 to 8 of Figs. 12, 13 the middle portions of the units are apposed end to end, so as to form a continuous thin band of grey separating the squares. No. 2 corresponds to the form of the illusion found in *Pseudoptics* (Milton Bradley Co., Springfield, Massachusetts). Here the thin grey band indicates the small interval separating two card-board sheets which slide against each other, edge to edge, the little dividing trench being usually so illuminated as to represent a grey which contrasts with both white and black. The illusion is present, in a slight degree, when no separation bands are present, as in No. 1, Fig. 12. It must, in this case, be assumed that the units of direction are formed by a slight amount of confluent union of pairs of opposite obliquely separated squares of the same luminosity. This confluent union is increased by a small area, disc or square, being placed in a position exactly between the two confluent squares. The unit of direction, in these circumstances, may be represented by that in No. 9 of Fig. 13, by omitting the grey areas and regarding the triangles as squares. The illusion in Figs. 12—14, on the whole, increases in degree from No. 1 to 14, that is, directly with the *increase in compactness* of the units of direction (as displayed in Fig. 15).

IX. *The nature of the 'unit of direction' illusion.*

Without attempting to offer a psychological theory as to the 'unit of direction' illusion, the writer may indicate certain negative and positive characters.

(1) There is not present in any form of the illusion any definite suggestion of perspective (derived from geometrical details), such as is present in the Zöllner illusion, and is advanced by some writers in explanation of that illusion.

(2) As the illusion is perceived as the result of $\frac{1}{8}$—$\frac{1}{2}$ second flash illumination, eye-movements are eliminated as a factor.

In the experiments described above in connexion with the coloured variants of Fig. 1, where the illusion is abolished or increased by the sudden interposition of a coloured medium, the writer fails, by introspection, to detect, as accompanying the change, any definite image or feeling of movement.

(3) In whatever ways the illusion may be related physiologically and psychologically to the Zöllner illusion, in the writer's case the two illusions are separated by one simple visual difference.

The illusion present in the Zöllner figure, and in all the variants of that figure, is abolished on steady fixation accompanied by steady peripheral attention. The 'unit of direction' illusion is distinctly modified under the same conditions but never abolished.

(4) There are possibly present as factors in the illusion two distinct visual *integrative* processes:

(*a*) One corresponding to a line joining the centres of areas of the units. This may be looked on as a form of confluent union.

(*b*) One representing collectively the trends or tendencies of the units.

The more clearly and discretely the units of direction are impressed on the median or peripheral (as distinct from the central) region of the retina, the more the second integrative process (*b*) tends to prevail. The nearer the units are to each other in serial position, the more they approach each other in luminosity (the more, in fact, the conditions favour confluent union) the more the first integrative process (*a*) tends to prevail.

In the LIFE figures, accordingly, the maximum degree of illusion is found in Fig. 1 ('twisted cord on chequered background'), and the minimum degree in Variant 1^e (1st series of variants of Fig. 1), where the black units in series touch each other at angular points. The second integrative process (*b*) in this latter figure (assuming the letters to be 7 inches long) ceases to be active when the figure is viewed at a distance beyond 15 inches.

If either of the coloured variants of Fig. 1 (*A* and *B*) be viewed at a distance of 15 inches and beyond, through a series of coloured media, in spectral order (extending between the complementary red and greenish-blue), the illusion gradually decreases in degree as the units gradually approach each other in luminosity, being abolished when the units are of equal luminosity.

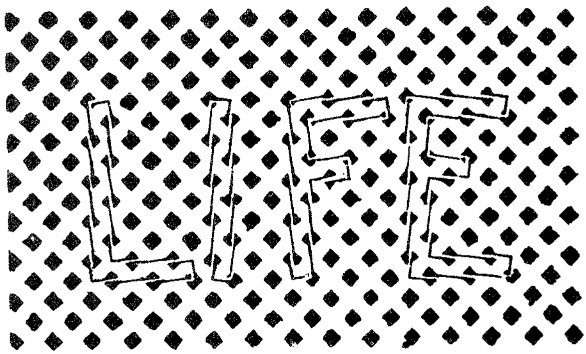


FIG. 1[a].

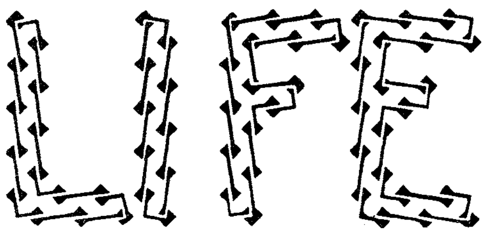


FIG. 1[b].

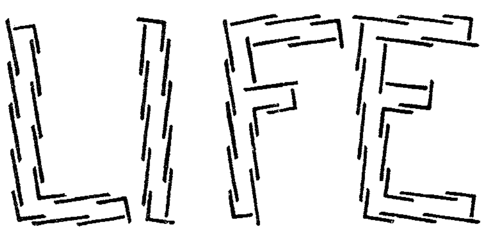


FIG. 1[c].

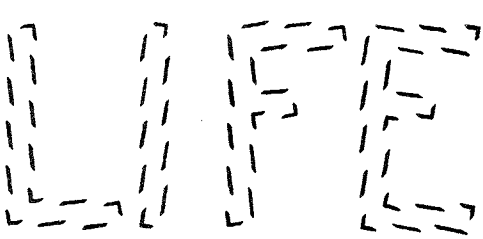


FIG. 1[d].

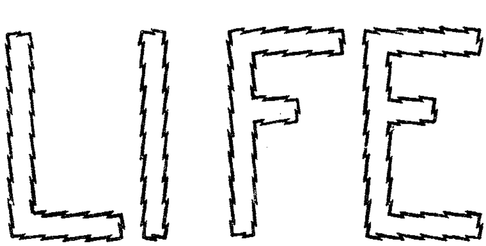


FIG. 1[e].

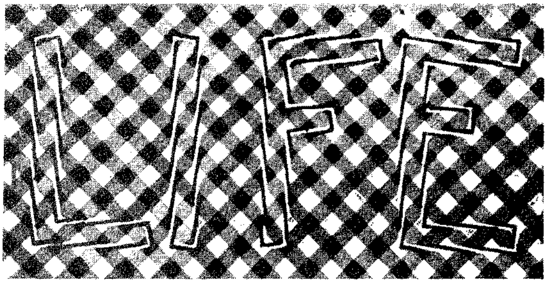


Fig. 1.

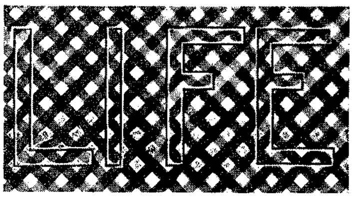


Fig. 2.

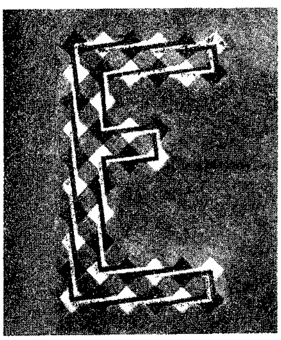


Fig. 1^{3a}.

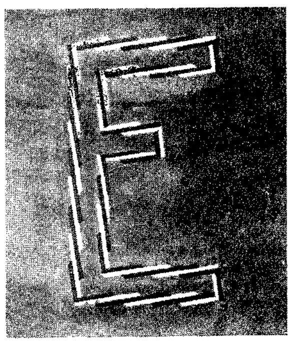


Fig. 1^{3b}.

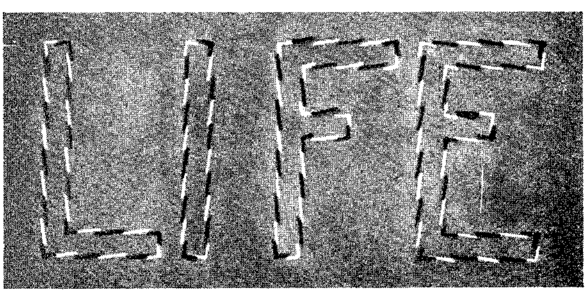


Fig. 1^{3c}.

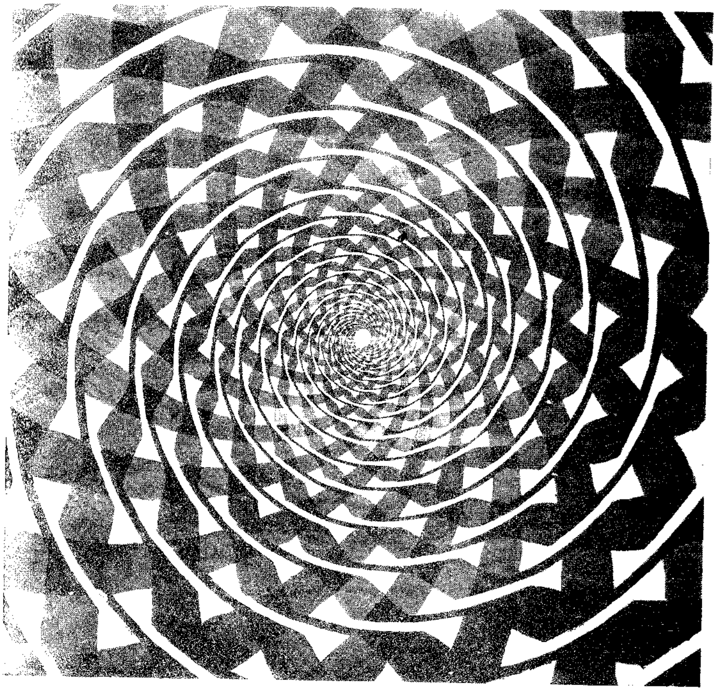
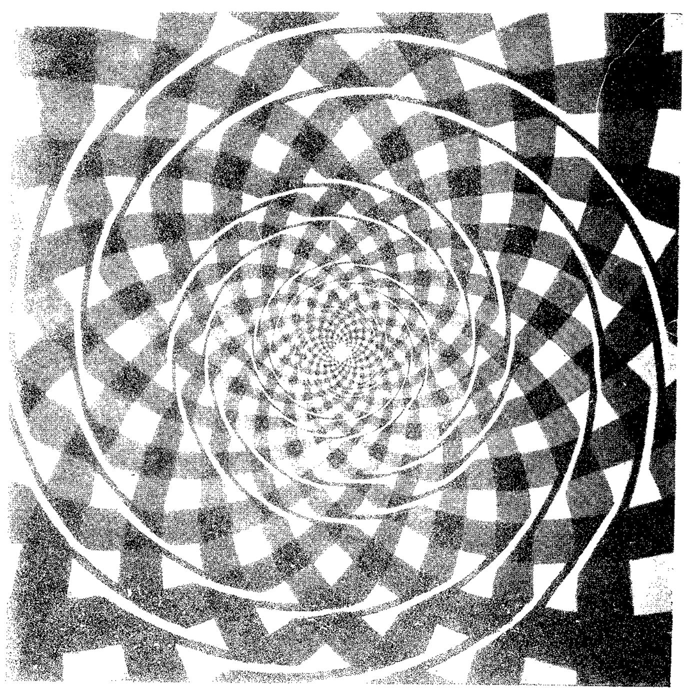


Fig. 2.



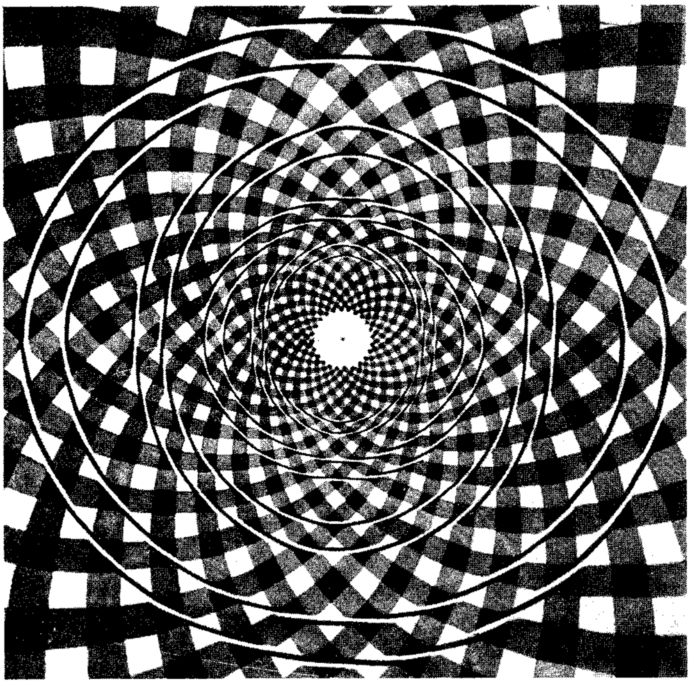


FIG. 5.

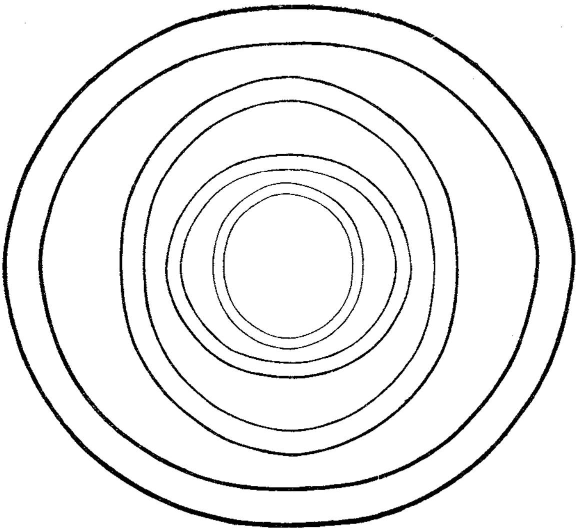


FIG. 5[a].

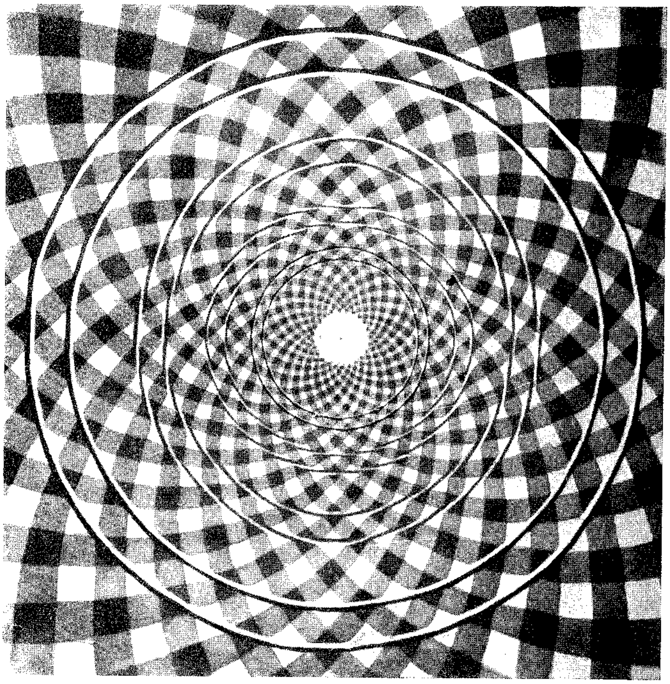


Fig. 6.

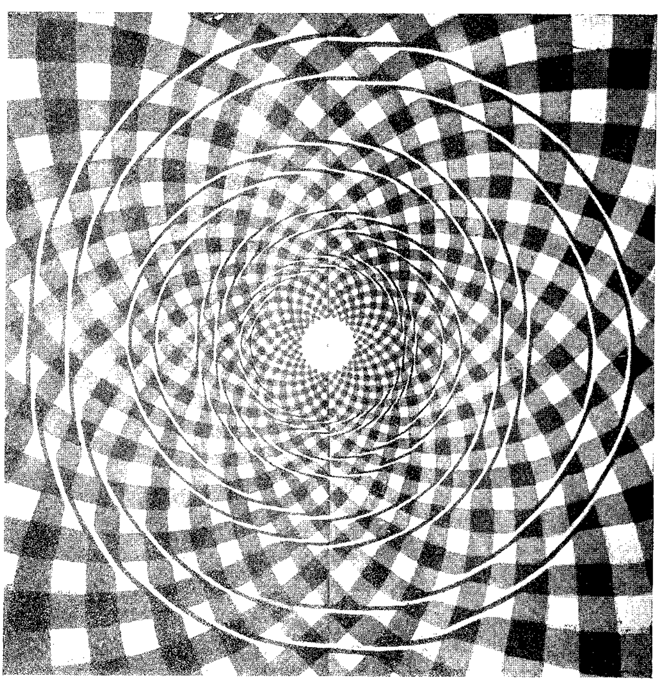


Fig. 7.

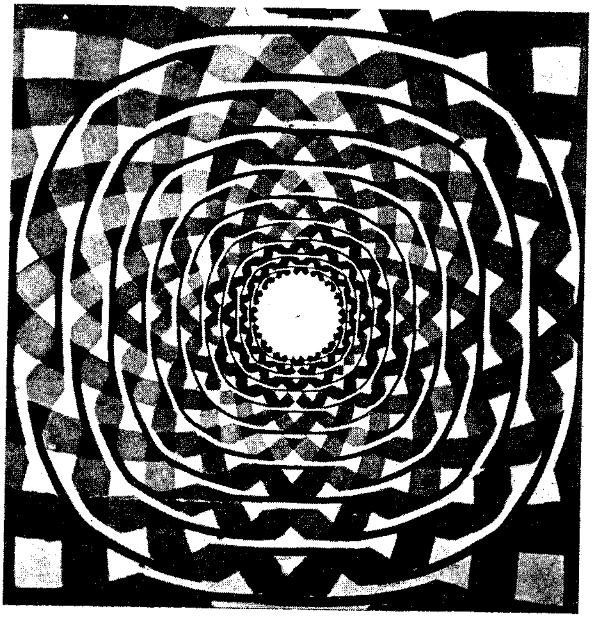


FIG. 8.

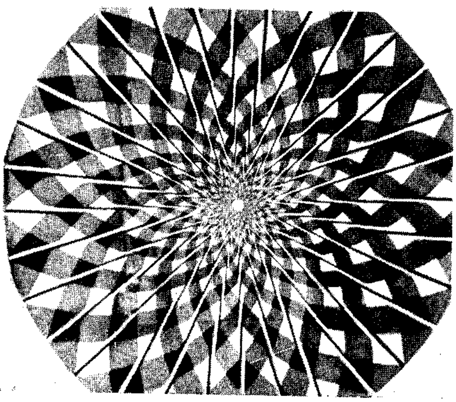


FIG. 10.

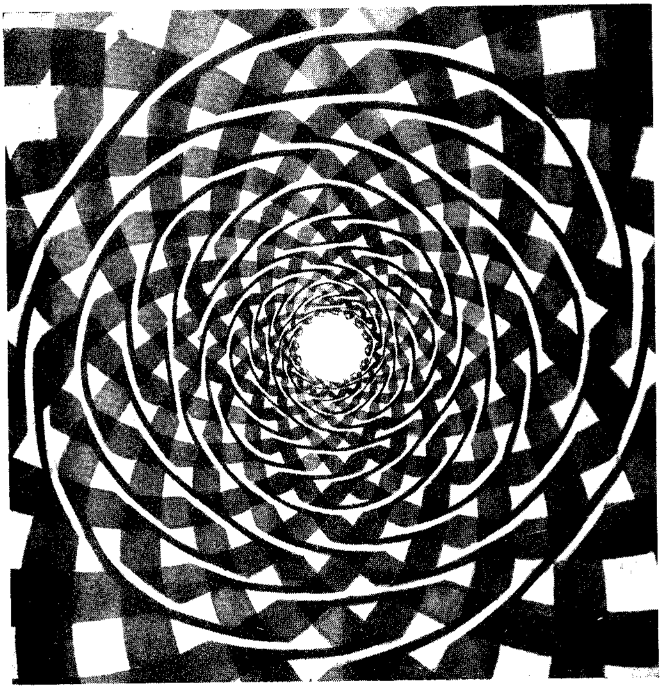


Fig. 9.

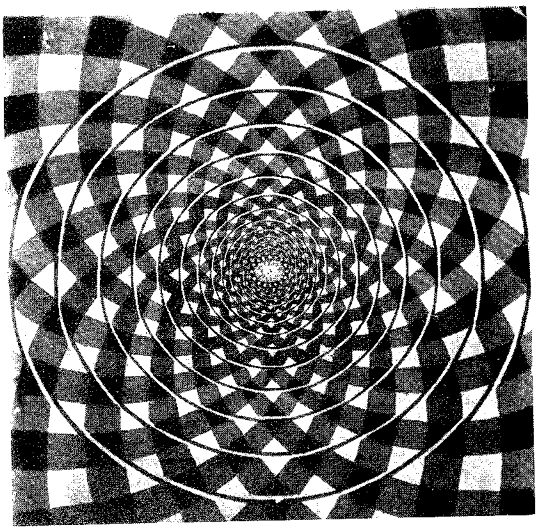


Fig. 11.

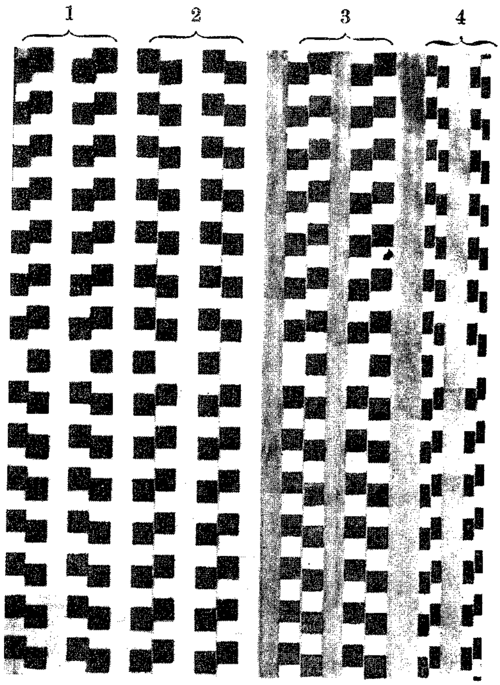


FIG. 12.

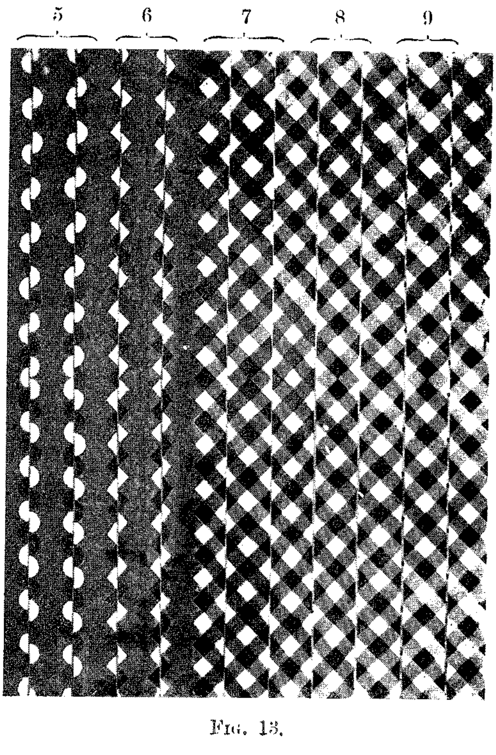


FIG. 13.

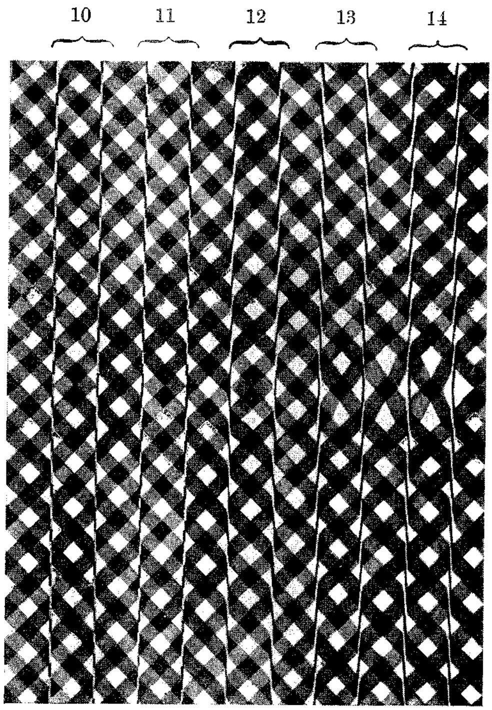


FIG. 14.

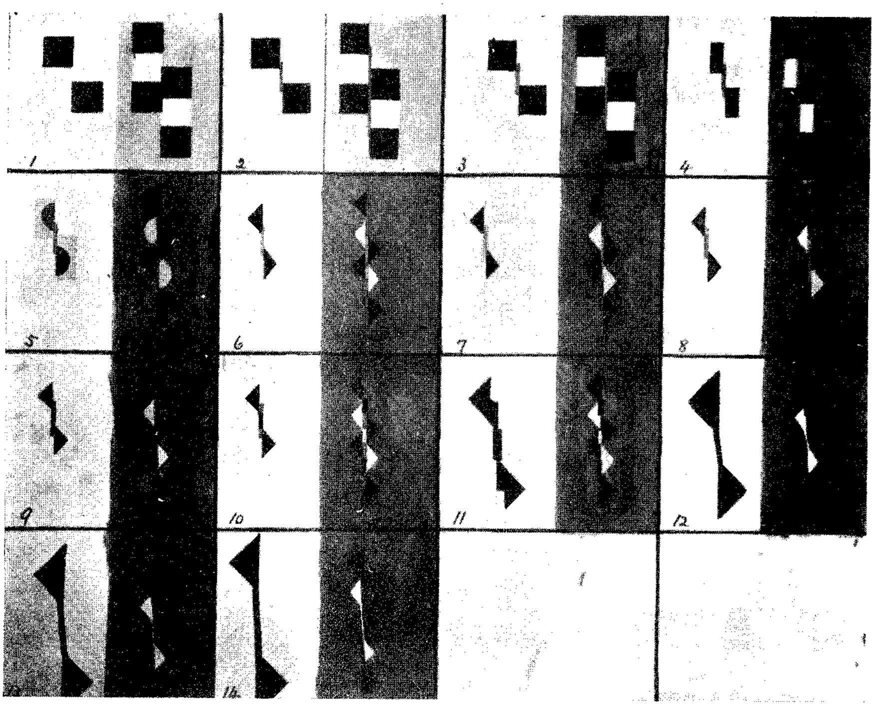


FIG. 15.