From Sensitive Chaos
The Creation of Flowing Forms in Water and Air
by Theodor Schwenk
Schoken Books NY, 1976

Archetypal Movements of Water

Circulating Systems and Spiraling Surfaces

Falling water separates off into drops

Wherever water occurs it tends to take on a spherical form. It envelops the whole sphere of the earth, enclosing every object in a thin film. Falling as a drop, water oscillates about the form of a sphere; or as dew fallen on a clear and starry night it transforms an inconspicuous field into a starry heaven of sparkling drops.
We see moving water always seeking a lower level, following the pull of gravity. In the first instance it is earthly laws which cause it to flow, draw it away from its spherical form and make it follow a more or less linear and determined course. Yet water continually strives to return to its spherical form. It finds many ways of maintaining a rhythmical balance between the spherical form natural to it and the pull of earthly gravity. We shall be discussing this play of movement with its rich variety of forms in the following chapters.
A sphere is a totality, a whole, and water will always attempt to form an organic whole by joining what is divided and uniting it in circulation. It is not possible to speak of the beginning or end of a circulatory system; everything is inwardly connected and reciprocally related. Water is essentially the element of circulatory systems.
If a living circulation is interrupted, a totality is broken into and the linear chain of cause and effect as an inorganic law is set in motion.
The cycle through the solid, liquid and gaseous phases may be counted among the best known circulatory processes of water.
Rising from oceans, lakes and rivers, it circulates with the air in the great atmospheric currents round the earth. Where it enters cooler zones, for instance when rising to pass over a mountain range, it contracts into clouds and falls back to earth as dew, rain, snow or hail. But only a small part—a little more than a third of the precipitation—finds its way towards the sea in streams and rivers. The rest dissolves again into the atmosphere and continues on in the great wandering courses of the low pressure areas or other air currents.
In this way water completes a circulation, from liquid through vapor

back to liquid, which it repeats about thirty-four times during the course of a year. Whether hurrying towards the sea in rivers, whether borne by air currents or foiling to the earth as rain or snow —water is always on the way somewhere at some point in, one of its great or small circulatory systems. Having seemingly arrived at its goal in the sea, it is swept on by the great ocean currents, in which it continues in its circulation on the surface or in the depths.
Currents of gigantic proportions fill the depths of the oceans. The extent of these huge currents is shown by the fact that the oceans

account for about 71 per cent of the surface of this earthly planet. When cooled to its point of greatest density, 4º C., water sinks (in salt water conditions are somewhat modified), while warmer water from the depths rises to the surface. On the ocean bed the huge masses of water that have sunk in the polar regions roll towards the equator, and later in far distant places return again to the surface. As we shall see, all stretches of water, every sea and every natural river, have their own circulatory systems.

The plant world plays a special part in the great circulation of water. As plants consist mainly of water a great stream transpires into the atmosphere from fields, meadows and woodlands. On a summer's day a 5,500 gallon stream of water is drawn through an acre of woodland into the atmosphere. In this way the plant world plays a direct part in the great life processes of the earth's organism. It is indeed a most important member of this organism, a channel through which water passes on its great circulating processes over and around the whole earth. For this same reason it is not possible to speak of an independent circulatory system of the plant. The visible streaming of the sap in the plant is only one half of its complete circulation, the other half exists in the atmosphere or in the earth. The plants are vascular systems through which water, the blood of the earth, streams in living interplay with the atmosphere. Together earth, plant world and atmosphere form a single great organism, in which water streams like living blood.

What is here spread out over a large space, animal and man have within themselves. What for the plant world is spread in circulation over the face of the whole earth they enclose in a small space, where it moves in just such rhythms and according to just such laws as the water outside in nature.

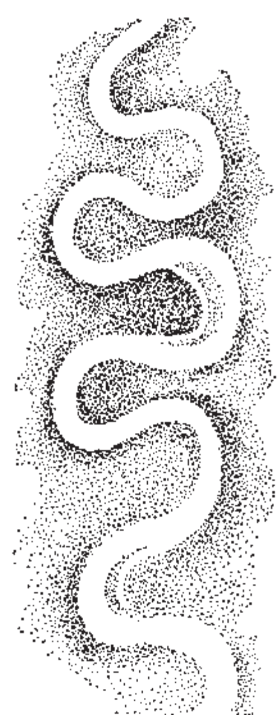
Just as in man's circulation there are, in the different organs, countless circulatory systems, which have their own specific tasks to perform, so nature too is full of all manner of great and small

circulatory systems, which carry out their own individual tasks and yet are intimately united with the whole. Every healthy lake, every marsh, is a living totality with its own vital functions, while at the same time it belongs to a greater community; it is the organ of a "living being"—the whole surrounding landscape in its own turn is a member of a yet vaster organism.

When we study all this we get a picture of water everywhere vitally active, combining and uniting in creative continuity as it carries out its varied tasks. Not only is it "body", subject to gravity; it is also an active element and the foundation of life. We must undertake the rather laborious task of getting to know not only the well known facts about water, but also many of its lesser known qualities.

Looking at a naturally flowing stream we notice the winding course it takes through the valley. It never flows straight ahead. Are these meanderings in the very nature of water? What causes water to follow such a winding course ? Its endeavor to complete the circle is here only partially successful, as it cannot flow uphill back to its starting point. Right at the beginning of its circulatory movement it is drawn downhill and in following this downward pull it swings alternately from side to side.

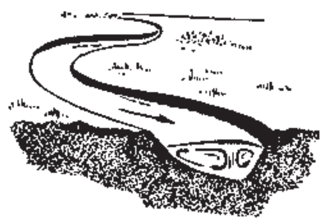
The rhythm of its meanders is a part of the individual nature of a river. In a wide valley a river will swing in far-flung curves, whereas a narrow valley will cause it to wind to and fro in a "faster" rhythm. A brook running through a meadow makes many small often only tentative bends. Stream and surrounding terrain always



Naturally flowing water always endeavors to follow a meandering course belong together, and the vegetation unites both in a living totality. In comparison, a river that has been artificially straightened out looks lifeless and dreary. It indicates the inner landscape in the souls of men, who no longer know how to move with the rhythms of living nature.

The meandering flow of water is woven through with a play of finer movements. These result in manifold inner currents which

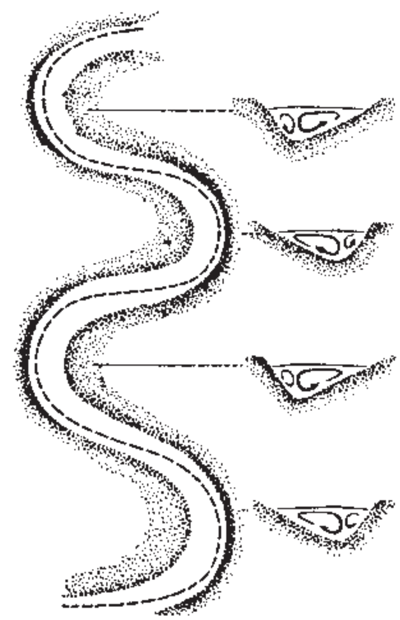
belong intimately to the life and rhythm of a river. As well as the movement downstream there is a revolving movement in the cross-section of the river. Contrary to a first superficial impression the water not only flows downwards but also revolves about the axis of the river.



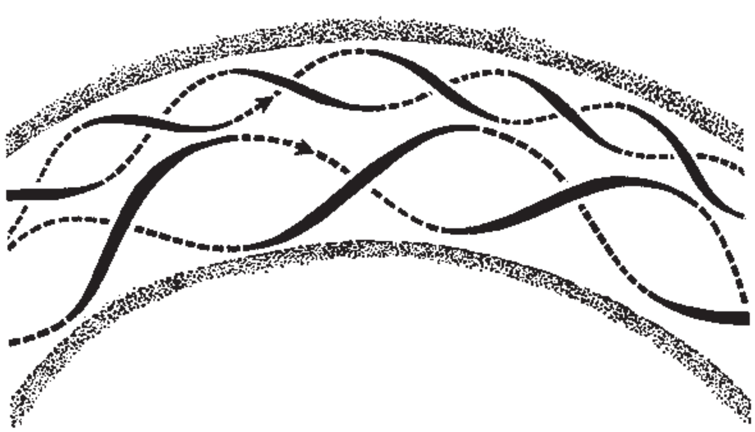
As well as currents flowing downstream there are also revolving currents in the bed of a stream

The direction of this revolving movement results from the fact that the water on the surface flows from the inside of a bend to the outside. There it turns downwards and returns along the bcd of the stream to the inner bank, where it rises again to the surface. The two movements together, the revolving circulation and the movement downstream, result in a spiraling motion. A closer examination will in fact usually show that two spiraling streams lie next to one another along the river bed.

Let us look at one point in the current, for instance near the bank on the inside of a bend. On the surface water is streaming outwards; but at the same time spiraling courses rise close by from the bed of the stream to the surface, so that in the stream the different spiraling currents flow through, above and below each other, interweaving from manifold directions. It is like the single strands which, twisted together, make a rope; only here we must imagine that everything is in constant change and also that new water keeps flowing through each single “strand” of water. This picture of Strands twisted together in a spiral is only accurate with respect to the actual movement. One does often speak of “strands” of water; they are however not really single strands but whole surfaces, interweaving spatially



The revolving secondary currents differ in size at the bend of a river. The larger one by the flatter bank on the inside of the curve becomees the smaller one near the steep bank on the outside of the next curve.



A spiraling movement is caused by the two secondary revolving currents together with the downstream flow (after M oiler)

and flowing past each other. The steam over a cup of tea or cigarette smoke as it rises in twisting and turning veils gives a clearer picture of what is meant.
These movements are the cause of the varying degree of erosion of the banks of a water course. The outer banks are always more eroded than the inner, which tend to silt up. The material scooped away from the outer bank wanders with the spiraling current to the inner bank further downstream and is deposited there.
Because of this process the river eats its way further and further outwards at the outer bank, swinging from side to side as it flows, thus making the loops more and more pronounced. They grow closer and closer to the form of a circle, and a flood will complete the process. Then the loops, which have till now contained flowing water, will be by-passed and form so-called backwaters.
Research on canalized rivers, for instance the Rhine in its lower reaches, revealed decades ago that the natural course of water is

The loops can become so pronounced through erosion that a flood can cause them to be by-passed and left aside as backwaters (after v. Billow)

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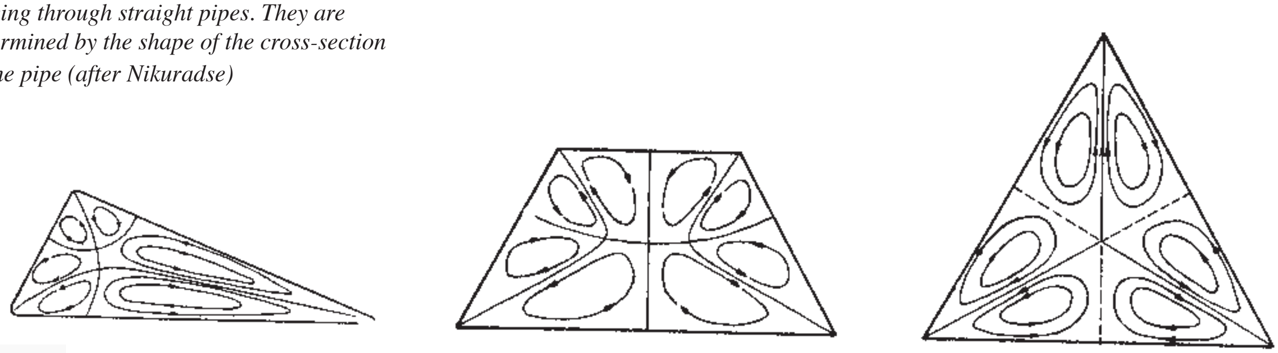
rhythmical meandering. Even between straightened banks the river tries, with what remaining strength it has, to realize this form of movement by flowing in a meandering rhythm between the straight banks. Not even the strongest walled banks can hold out indefinitely against this “will” of the water and wherever they offer a chance they will be torn down. The river tries to turn the unnatural, straight course into its own natural one. A meandering motion lengthens the course of the river and thus slows down the speed at which it flows. In this way the river bed is not hollowed out, and the ground-water reserves are left intact.
In straight pipes, too, especially those with an angular cross-section, internal movements come about that are similar to meanders where one would at first assume that the water would flow straight ahead. Separate smaller secondary circulatory systems fill the cross-section of the pipe and together with the main forward flow create moving, spiraling surfaces.
It can happen that parts of the liquid in such a spiraling current on approaching a neighboring current pass over into it. Here too an interesting movement to and fro in the pipe—after the fashion of a meander—can come about.

Backwaters of the Mississippi (after Peschel)

Secondary currents also occur in water flowing through straight pipes. They are determined by the shape of the cross-section of the pipe (after Nikuradse)



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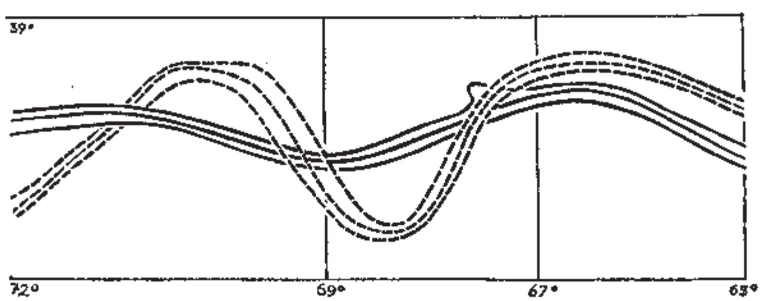
Even where there are no fixed banks to confine the current it flows in rhythmical curves, for instance in the oceans, where whole systems of currents, like the Gulf Stream, flow along in the midst of the ocean waters. The Gulf stream follows its meandering course from the Gulf of Mexico through the Atlantic Ocean to Northern Europe. Warm water flows in the form of a gigantic river in the midst of colder water and builds its own banks out of the cold water itself. 1.



In the Atlantic Ocean the warm Gulf Stream flows through colder water, describing great loops that change their position during the course of time {after Fuglister)

One and the same principle, then, becomes manifest in all dimensions of flowing water, from the small trickle with its little, rhythmical loops, through rivers whose loops grow ever larger, to the loops of the ocean currents surrounding the earth. We see here an archetypal principle of flowing water that wants to realize itself, regardless of the surrounding material.) The surrounding material can be on the one hand the hard rock of the mountains, the ice of the glacier with its little channels formed by the water from melting ice, or again, scree, gravel or soil. On the other hand it can consist of warmer or colder water. Regardless of the surrounding material, the current creates for itself a complete, meandering river bed. Even if the surrounding material is organic substance, or even air, the flowing medium still behaves according to the same principle, as we shall show later on. This is a formative principle which appears under the most widely differing physical conditions and is not affected by them. The Gulf Stream is an example not only of this principle of move-

1. Owing to the easily displaceable nature of such great masses of water the rotation of the earth is of course not without influence. We shall however not go into the complex character of this movement here.

ment in a flowing medium, but also of another ruling principle. The loops of the Gulf Stream shift their position rhythmically to and fro during the course of a long time. Not only are the loops themselves arranged in rhythmical succession but they change their position rhythmically. The Gulf Stream has a rhythmical form in *space*, and it is also subject to a rhythmical process in *time* through the changing position of its loops. The same thing, taking place over lengthy periods of time, can be observed in all natural watercourses. This is another expression of the nature of water; it burrows in a rhythmical course into its surroundings in space and is moreover subject to the "course of time" which gradually alters the spatial arrangement of its meanders. The relationship of water to time is clearly manifest. We must attempt to reach an understanding of this relationship in order to apprehend the true nature of water, of movement in the organic world and therefore of life itself.

Everywhere liquids move in rhythms. Countless rhythms permeate the processes of nature. Not only are the great currents and tides of the oceans subject to the rhythms of the seasons; every lake, every pond, every well with its ground-water level has its movements that fluctuate with high and low tide or according to other laws.

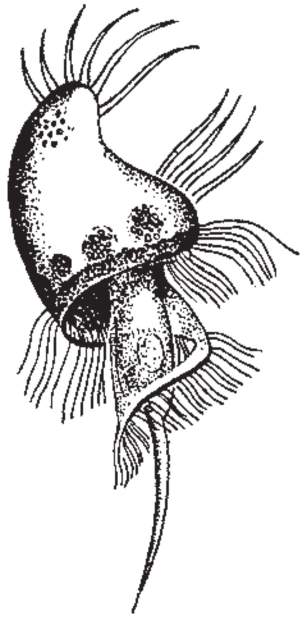
All naturally flowing waters have their rhythms, perhaps following the course of the day, perhaps keeping time with longer seasonal rhythms. Thus there are times when rivers burrow in the depths, and others when they spread out in width. Lumbermen are well acquainted with this fact. At times the river pushes the logs outward to the banks while at other times they stay in the middle of the waterway.

Let us recapitulate briefly: We demonstrated how water tends to form into spheres; and we saw that even when moving it attempts to retain this spherical principle through circulation. Moving along spiraling surfaces, which glide past one another in manifold winding and curving forms it expresses the conflict between its own natural inclination to the sphere and the force of gravity acting upon it. The current with its rhythmical arrangement in space is subject to greater or lesser rhythms in time, often according to very strict laws.

A few examples from the world of living creatures will further illustrate well this inner propensity of water. Every living creature, in the act of bringing forth its visible form out of its archetypal idea, passes through a liquid phase. Some creatures remain in this liquid state or solidify only slightly; others leave the world of water, density, and fall to a greater or lesser degree under the dominion of

the earthly element. All reveal in their forms that at one time they passed through a liquid phase.

The question however arises: Do the forms of the living organisms merely betray the character of the watery phase through which they have passed, or is it that the water itself, impressionable as it is, is subject to living, formative forces and creative ideas of which it is but the visible expression ? If so, water as such would be the embodiment of a world of higher forces penetrating through it into the material world and using it to form the living organisms. This is a fundamental question which we shall consider later on; it will in part be answered as we proceed.



Many unicellular water animals haw incorporated the archetypal spiraling movement of water in their shapes. Thy even usually propel themselves along with a screw-like movement (from Ludwig, after Kahl)

The infusoria are creatures only slightly solidified and hardly differentiated out of their watery surroundings. Many of them reveal the combination of spherical form and direction of propulsion in their screw-like spiraling shapes, which make locomotion possible. The flowing movement of fishes fins is intimately related to the water. Moving as they do like densified veils of water, they embody and make visible the moving forms of the water itself. It is the same principle which comes to expression in organic form, in its function and in the surrounding medium. All three flow into one another in movement (Plate 15).

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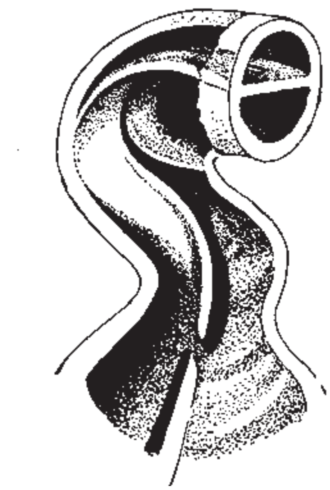
The sketch of the branchial filament of spirographis speaks for itself. A tube-worm native to the Mediterranean, spirographis allows its tentacles to play spirally in the water and when stimulated jerks them spontaneously back into its tube along a screw-like form. Its gill filaments form a perfect spiral.

Spirographis manifests a spirally winding surface even in the delicate build of its gill filaments (after Ludwig)

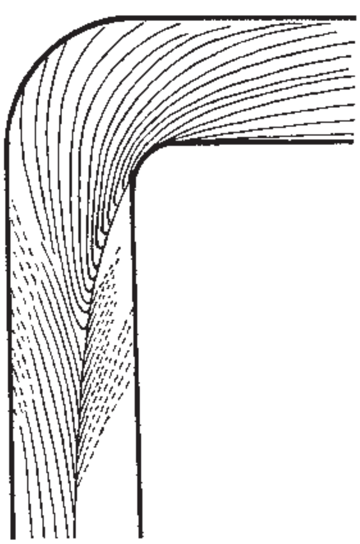
Not only creatures swimming in water but also organs through which water flows are inclined to be spirally formed. In the example of the Gulf Stream we saw that different liquids—for instance warm and cold water—can flow side by side for a long time without any appreciable intermingling. A common example is the confluence of a clear and a muddy stream, where both currents often continue to flow quite a way side by side, separate, yet in close contact along a fairly distinct dividing line.
We see the same phenomenon where arterial and venal blood flow together in the heart and a dividing wall forms where they meet. This dividing wall becomes ever more marked in the advancing sequence of animal development. Though the blood of animal and man is actually a suspension of cells in a liquid, nevertheless phenomena fundamental to a flowing liquid occur here too.
An example is the African lung-fish (Protopterus), in whose heart the dividing wall is an impressive spiraling surface separating the two kinds of blood. As can be seen from the example of the Gulf Stream, the two streams are separate from the start.
The sketch below depicts this process as it occurs in a bent pipe (a wide blood vessel). Following the centrifugal force, the flowing



In the heart of one of the lung-fishes (Protopterus) a dividing wall in the shape of a twisted spiral surface has developed between the two neighboring blood streams

water (blood) pushes towards the outer wall, thus giving rise to two circulations which meet in the central zone. Were a wall to be placed where they meet, the course of the movement would hardly be affected.[1]
We see that a surface remains free into which the living material can grow, making visible what was preformed by movement. The sketch shows this process for the course of the whole bend in the vessel or pipe. The dividing surface which is vertical at entry twists to the horizontal on leaving the bend. If a pipe is painted inside with

Secondary currents in the bend of a pipe or of a wide blood vessel



The inside of a bent pipe was painted with a plastic varnish into which the flowing liquid could impress its course (after Hinderks)

a plastic varnish the water flowing through can impress its own course into it. The accompanying sketch shows these courses. If one remembers that the separate courses lie on the cylindrical wall of the pipe, it is clear that they are doubly bent and twisted—like the thread of a screw. Now as the forces of the flowing water simply demand the spiraling form, an elastic vessel will be twisted to a certain extent through the movement of the liquid, and with it also the above mentioned liquid surface of contact. The living material has only to grow into this curled dividing surface in order to make it

1. In *narrow* pipes on the other hand there is always a so-called laminar movement, i.e. water flows in separate layers, parallel in the cross-section, without any appreciable secondary currents or eddies.

visible. That such spiraling forces actually do occur in elastic vessels with liquid flowing through them can be shown by an experiment with the garden hose-pipe, which writhes back and forth like a snake, when let loose, and cannot be subdued till the end is held steady or the tap turned off. In comparison with the flow of blood these forces are of course much stronger. We shall forbear to analyze this process in greater detail, as we are above all concerned with the forms which arise in flowing liquids. From what we have seen we can already say that such a significant formation as the dividing wall of the heart can be understood out of the movements of the medium flowing through it, and that it is not necessary, as is go often done, to look for utilitarian explanations.

In the intestine of Protopterus and other lung-fishes there is also a spiral fold (after Newton Parker)

The lung-fishes reveal the already mentioned formative tendency in their intestines. Along the inner wall of the intestine is a well-formed spiral fold, revealing the laws of flowing media in its winding surfaces. The contents of the intestine are of course to a great extent still subject to the laws of liquids.

Let us recall the fact that water endeavors to round itself off into a sphere, to become an image of the whole cosmos. If a directional force is added to this, for instance the force of gravity, then the combination of the two—sphere and directional force—will result in a screw-like or spiraling form.

The child before birth is in a protective envelope of water, prior to his final entry into the sphere of earthly activity. As though lying within a sphere he moulds his as yet liquid form, which gradually becomes more condensed. On being born he leaves the spherical space of water and enters into a relationship with the directional forces of the earth. The more he yields to these forces the more his body becomes solidified, which is essential to standing upright and learning to walk. One of the ways in which his origin in the spherical nature of water—the cosmos—and his orientation towards, and interplay with, the earth are revealed is in the forms of his limbs. The spiraling forms of muscles and bones bear witness to the living world of water and also to a purposeful aim towards mastery of the solid and are reminiscent of the way water flows in meanders and twisting surfaces in the interplay between resting in spheres and being drawn in an earthly direction. (These formative principles arc also found in the muscles and bones of the higher animals.)

Spiraling surfaces can be found in the structure of many bones; human humerus

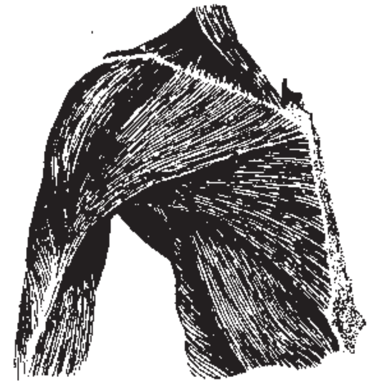
We have seen how the water in rivers describes curving and twisting surfaces. Such surfaces can be clearly demonstrated by letting water flow out of a container in a wide stream. The stream spirals as the

water slips below the edge of the container. This process can often be seen beautifully in fountains where the water falls from basin to basin.

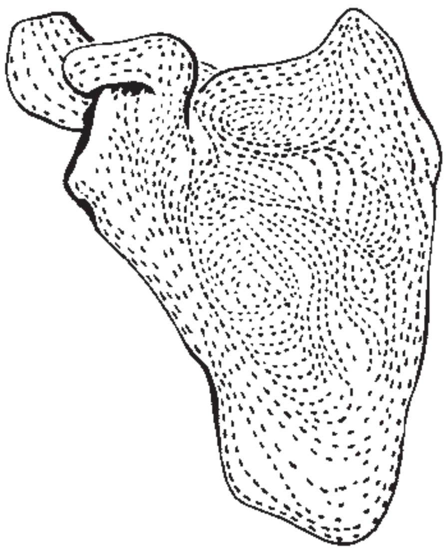
Many limb muscles manifest these spiraling forms. Through the limbs, too, whole systems of currents stream and the muscle more or less follows them. Both muscles and vessels speak of the same thing: streaming movement in spiraling forms. This movement runs through the sinews into the bones. The bone has raised a monument in “stone” to the flowing movement from which it originates; indeed one might say that the liquid has “expressed itself” in the bone.

By a special method, for which we owe acknowledgment to Benninghoff, it is possible to demonstrate the streamlined structure

of a bone. Small holes are made with an awl at different points in the decalcified bone and then filled with a colored liquid, for instance Indian ink. These small holes do not remain round, but in time will be seen to lengthen out, revealing the directions of tension in the bone. If the little fissures arc then continued and joined up, the otherwise hidden “systems of currents” in the bone will be made visible. Benninghoff has examined many bones with this method, of which the sketch below is intended to give an impression. These

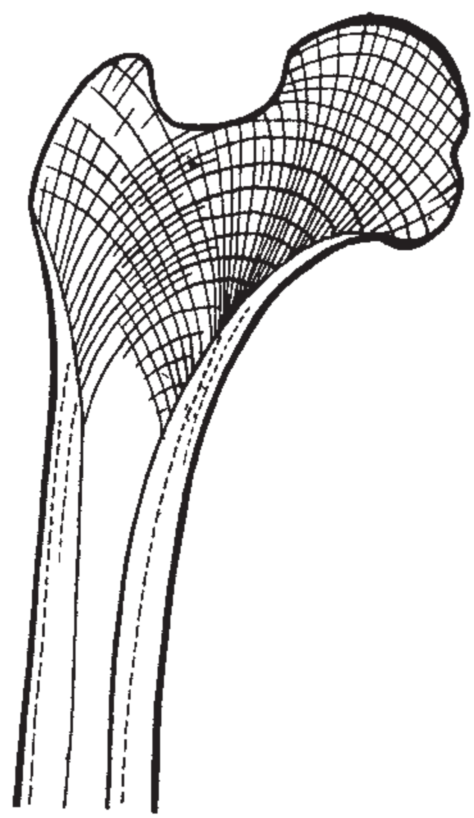


Muscles of the chest and upper arm in the human being.



The systems of tiny fissures in many bones show looped and spiraling forms reminiscent of the laws according to which water flows. Human shoulder blade (after Benninghoff)

systems of currents can be followed right into the bone, where they finally form the familiar spongy bone structures and become incorporated into the static and dynamic forces of standing and walking. Thus again a circle is completed, for statics and dynamics are brought into play by the muscles. And behind them is the invisible human will, which even before any movement becomes visible sends a stream of blood to the muscle which is to be moved. In the quiescent, finished forms of vessels, muscles, ligaments, sinews and bones the same flowing movement can be detected which leads these organs to their varying degrees of density and solidification in such a way that finally in each single organ the underlying spiraling process remains clearly recognizable. And do we not see this flowing movement—in rhythmic sequence—even in the great variety of movements of the human limbs ? From what has been said it is however also clear that not all organic forms can be explained simply by the laws of flow. For in the last resort every living form is the expression of an underlying archetypal being.



The “lines of flow” on the surface of the bone can be followed right into the interior, where the)’ end in the spongy bone structures. Human femur (after J. Wolf)

THEODOR SCHWENK

SENSITIVE CHAOS

THE CREATION OF FLOWING FORMS IN WATER AND AIR

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Illustrations in the text
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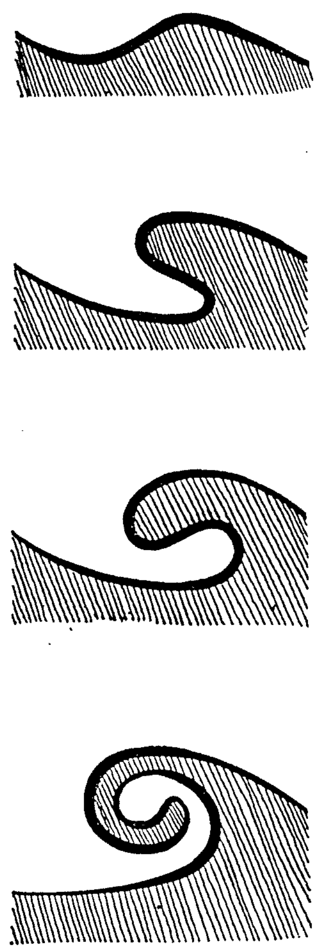
All that is rhythmical in the nature of a wave, where the contiguous elements—water and air for example—remain separate, becomes altered as soon as the wave begins to break. It folds over and curls under, forming hollow spaces in which air is imprisoned in the water. The elements, which have till now been separate, unite in turbulence and foam, overlapping and forming hollow spaces. At the same time the foaming water disintegrates into vapour, entering the air in a rhythmical succession of misty clouds.

Wherever hollow spaces are formed, when upper layers of water overshoot the more slowly moving lower layers, the water is drawn into the hollows in a circular motion. Eddies and vortices arise. If we could watch the process in slow motion we would see how a wave first rises above the general level of the water, how then the crest rushes on ahead of the surge, folds over and begins to curl under. This presents us with a new formative principle: the wave folding over and finally curling under to form a circling vortex.

Dividing surfaces or boundary layers appear not only between water and air, but also in the midst of water itself, for instance at the confluence of two rivers, or where the water is parted by an obstacle and then meets again. Here too a surface of contact arises where the two meet. Where streams of water flow past each other at different speeds we also find surfaces of contact; like the surface between water and air, these surfaces will become waved, overlap and finally curl round (Plate 23). We are here concerned with the processes taking place at the actual surface of contact, and not with their position in space, which may be horizontal or vertical. The processes at these boundary surfaces are in every case the same as those on the surface of water: the wave-formation, the overlapping and the curling round of the layers. These processes can be more easily observed when the boundary surfaces are vertical; when they are horizontal, as in the natural wave formation described above, the process of vortex formation takes place much more under the influence of gravity and therefore the whole thing is more liable to collapse in foam.

In every naturally flowing stream we can see what happens at the boundary surfaces, where for instance a twig from a bush on the bank hangs into the water, or where the water has to flow round a stone. The flowing water is parted by the obstruction and unites



A wave curls over to form a vortex

again when it has passed. But the little obstruction causes a cleavage, a dividing line, a boundary surface in the water, which bulges out into a wave alternately to one side and then the other, folds over and curls into a vortex. On both sides of the boundary surface a series of small alternate vortices arises, which travel downstream with the current.

In a clear stream the vortices appear as small round hollows, in which sometimes small bits of wood or pollen spin round. If the sun shines on the water they are projected as small circular discs in a regular pattern on the bed of the stream.

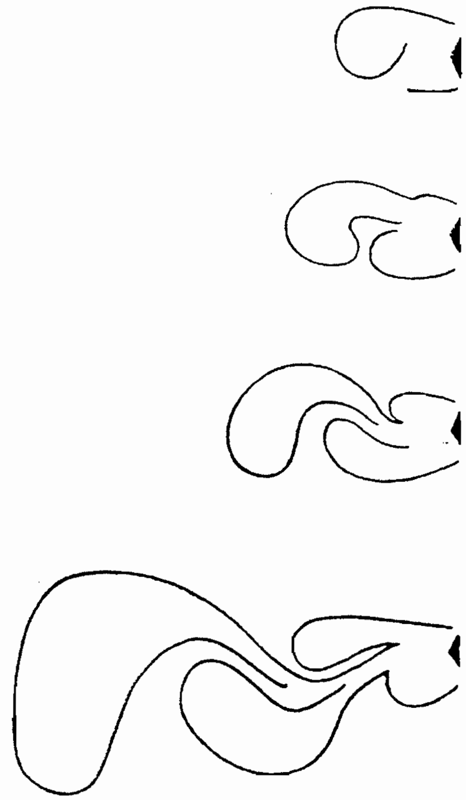
A distinct train of vortices (after Homann)

Wherever currents of water meet, after a single current has been parted by an obstacle, for instance by bridge piers, or when two different streams meet, the confluence is always the place where rhythmical and spiralling movements may arise (Plate 23). Also where water flows into a lake the same rhythmical movements and vortices occur at the boundary surface between the moving water of the stream and the still water of the lake. Every curving movement in the boundary surface may lead to the formation of an entirely new form, which lives its own individual, whirling life within the current of water, namely, the circling vortex (Plate 37).

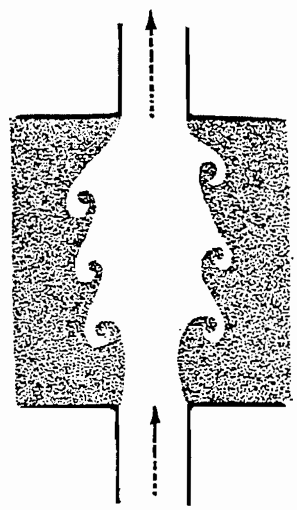
Boundary surfaces of the kind we have been describing occur wherever there are flowing currents, but they are usually invisible, for they do not show up in clear transparent water.

It can be observed that in every stream the water at the edges flows more slowly than in the middle. In other words, faster layers flow past slower layers and this means that very extensive inner surfaces come about as layer after layer flows by. The same can be observed in pipes. In the thinnest pipes, where there can be no question of vortices, the layers at the edge move considerably more slowly than those in the centre (laminar flow). (Some idea of the development of inner surfaces, as these layers flow past each other, can be gained if one imagines how the pages of an unbound book slide over each other when they are bent back and forth.) If the difference in speed between neighbouring layers reaches a certain degree, vortex formations occur. These always originate in the surfaces of contact between different elements concerned in the movement, for example something resting and something moving, a hard edge and the flowing water, and so on. So-called turbulence in a current of water has to do with the instability of these surfaces of differentiation in relation to the speed of the flow.

This is the archetypal phenomenon of vortex formation. Wherever any qualitative differences in a flowing medium come together, these isolated formations occur. Such differences may be: slow and fast; solid and liquid; liquid and gaseous. We could extend the list: warm and cold; denser and more tenuous; heavy and light (for instance,

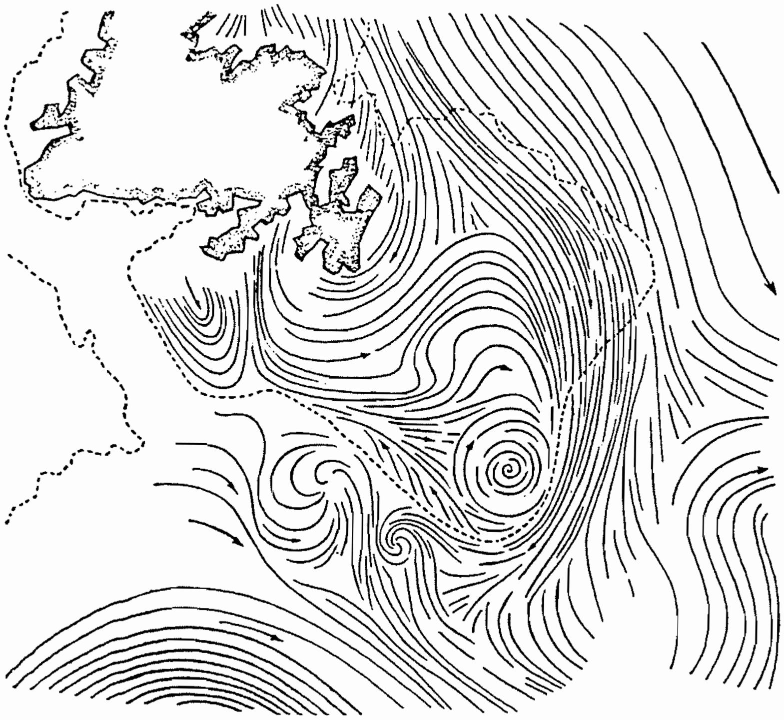


Beginning of a train of vortices (after Walter)



Whirling, mingling movements occur when warm water streams into cold or vice versa

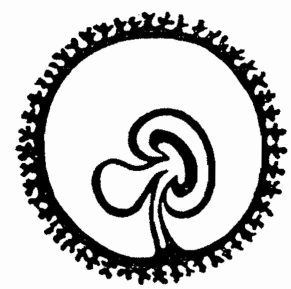
salt water and fresh); viscous and fluid; alkaline and acid. . . . At the surfaces of contact there is always a tendency for one layer to roll in upon the other. In short, wherever the finest differentiations are present the water acts as a delicate "sense organ" which as it were perceives the differentiations and then in a rhythmical process causes them to even out and to merge.



The formation of vortices occurs on a large scale where great masses of water of different temperatures meet. Mingling currents off Newfoundland

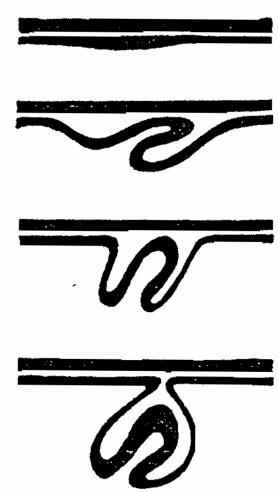
The full development of a wave leads to the overlapping and rolling in of layers of water, resulting in circling moving forms which lie isolated in the general current and travel with it. In the undulating, to and fro movement, which persists as long as the wave retains its form, neighbouring media of differing qualities only touch; but they intermingle thoroughly as soon as the wave form breaks and creates hollow spaces in which for instance air is enclosed, as in breakers on a beach or vortices in a current. Not only air, other substances may of course become imprisoned in the hollow spaces, depending on what opposing elements are in contact *before* the inward curling movement occurs. As soon as different media, even different qualities within the *same* medium, flow together, for instance warm and cold water, the one is taken into the other so that the hollow space, like a vessel, is filled with water of a different quality. The important thing here is that *hollow forms* arise, which can be filled with another medium, just like any receptacle.

The hollowing out of inner spaces is a fundamental process—an archetypal form-gesture in all organic creation, human and animal, where in the wrinkling, folding, invaginating processes of gastrulation, organs for the development of consciousness are prepared. Forms arising out of this archetypal creative movement can be found everywhere in nature.



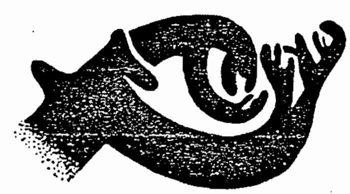
Early stage in the development of the human embryo (after Clara)

This important phenomenon—the curling in of folds or layers to create a separate organ with a *life of its own* within the whole organism of the water—does actually occur in the forming of organic structures. The differences of speed in the fluid flow correspond to the different speeds of growth or development in an organic form. Slower or more rapid growth of neighbouring layers leads to the overlapping, folding, involuting and invaginating in the process of which the organs are developed. Like vortices, organs have their own life: they are distinct forms within the organism as a whole and yet in constant flowing interplay with it. A great example of this process is the pupa of a butterfly. The organs, at first curled up, are pushed out when fully developed and appear as feelers, limbs or the like.



In the rigid chrysalis of a butterfly, growth takes place at varying speeds. This leads to folding processes in preparation for the forming of the organs (from Eidmann, after Weber)

The first stages of this archetypal movement also occurs in the plant world. At the growing tip wave-like bulges appear which later fold over and develop into leaves which open up into the air. In general the plant stops short of the actual vortex development. Only in the forming of the blossoms is there a suggestion of inner hollow spaces; there we are reminded of the world of butterflies and insects—in



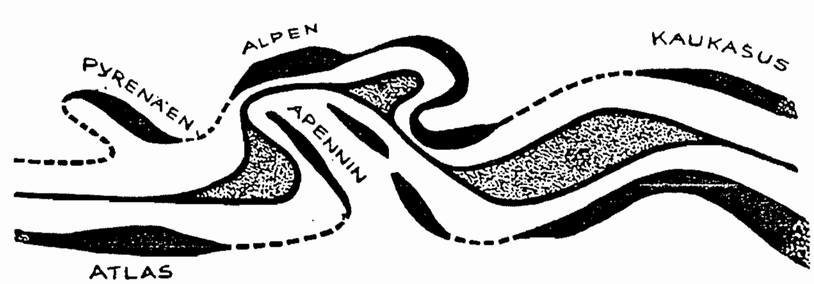
Shoot of an alga (after Goebel)

fact, of animal development. Indeed, we often see the plant even unfurling from the spiralling form into the flat, expanding form of the leaf, for example, in the fern (Plate 44).

Boundary surfaces, with their rhythmical processes, are birthplaces of living things. It is as though the creative, formative impulses *needed* the boundary surfaces in order to be able to act in the material world. Boundary surfaces are everywhere the places where living, formative processes can find a hold; be it in cell membranes, surfaces of contact *between* cells, where the life forces are mysteriously present; in the great boundary surfaces between the current systems of the oceans, where various currents flow past each other in different directions—these are known to be particularly rich in fish; or in the infinitely extensive surfaces of the natural and artificial filter systems of the earth, where the water seeping through is purified and given back its vital qualities.

Leaf nodes at the growing tip (after Sachs)

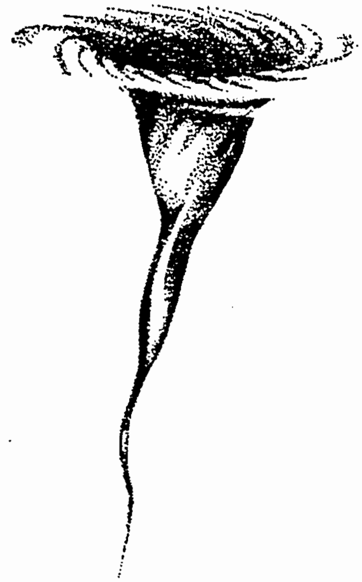
A similar process akin to the formation of organs must have taken place in the great stages of development of the planet earth, when it was still in a fluid state, processes which are today so to speak petrified and at rest in the crust of the earth. They are to be found in many places in the mountain ranges, or inside the earth—for instance in excavations. They point to youthful stages in the development of the earth, when it was obviously still permeated by



Folding on the surface of the earth: the great mountain ranges of Central Europe and North Africa living organic processes. In his book *Lebensstufen der Erde,* W. Cloos describes these early life processes of the planet earth in a grand panoramic review of geology. These formative principles can be traced right into the fine structure of the rock, in which the great processes—creating and assorting matter—have as it were projected themselves. We can come to understand them by learning to know the archetypal movements of all living matter and the movements of water—the element of life. The whole globe must have been penetrated through and through with these life-processes in the distant past.

Vertical section of the Alps in the region of the Simplon Pass. Length of the section about 16 miles, depth about 6 miles (after C. Schmidt)

North-south section through the eastern Alps



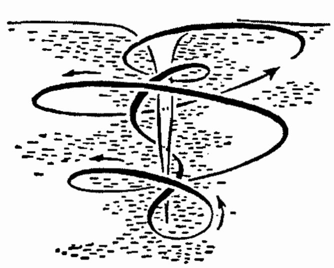
Vortex funnel

All flowing water, though it may seem to be entirely uniform, is really divided into extensive inner surfaces. If vortices form behind a stone or a bridge pier, these layered inner surfaces will of course also be drawn into the whirlpool, flowing past each other in a circular or spiral course. As water is transparent this process is difficult to observe unless colouring matter is used. Then one can see how the inside of the vortex turns faster than the outer part, and how the revolving layers glide past each other (Plate 37). It is a form which has separated itself off from the general flow of the water; a self-contained region in the mass of the water, enclosed within itself and yet bound up with the whole.

Closer observation reveals that this vortex has a rhythm of its own. Contracting at one moment, it stretches itself downward, extending with its lower end right into the depths; at the next, expanding in breadth, it draws up the tapering inner layers again. Then follows a renewed contraction, together with an extension downward, which is again withdrawn to spread out in breadth and so on. It is a rhythmic pulsation.

A picture of the process can be gained by causing water in a cylindrical vessel to whirl round so that a funnel-shaped vortex arises, to which a drop of colour is added. It is then easy to see how the outside layers turn more slowly than those inside and how the whole form pulsates rhythmically up and down. Especially the inner layers describe corkscrew-like surfaces which become more pronounced as the movement slows down. This archetypal movement of water in spirally winding surfaces has already been described in the first chapter.

Water around a whirlpool moves in spirals



We come to realise that the vortex is a figure complete in itself with its own forms, rhythms and movements. On closer examination we find that the vortex with its different speeds—slow outside, fast inside—is closely akin to the great movements of the planetary system. Apart from minor details, it follows Kepler's Second Law of planetary movement: a given planet circles round the sun as though in a vortex in as much as it moves fast when near the sun and slowly when further away. This law applies to the whole planetary system, from the planets nearest the sun to those furthest away. The vortex in its law of movement is thus a miniature image of the great planetary system. Its outer layers, like the planets furthest from the sun, move more slowly than its inner layers, which circle more quickly round the centre, like the planets nearer to the sun. The sun itself would correspond to the centre of the vortex. Strictly speaking the "circling" of the planets is of course eccentric.

The vortex has yet another quality that suggests cosmic connections. If a very small floating object with a fixed pointer is allowed to circle in a vortex, the pointer always points in the direction in which it was originally placed, that is, it always remains parallel to itself! In other words it is always directed to the same point at infinity. It can of course be started off pointing in any direction and it will then remain pointing in this direction while circling in the vortex. This shows how a vortex is orientated—as though by invisible threads—with respect to the entire firmament of fixed stars.

A small piece of wood circling in a vortex. It constantly points in the same direction

The vortex is, therefore, a system depicting in miniature the great starry universe; its orientation in space corresponds to the fixed stars and its inner laws of movement to the solar system with its planets. The sun itself corresponds to the suction centre of the vortex, where the speed is theoretically infinitely great. But as infinitely great speeds are not possible on earth, the dense water vaporises in the suction centre, which is then filled with air, the substance next in density. This is sucked into the screw-like spirals of the vortex in a pulsating rhythm (Plate 41).

In his book *Technische Strömungslehre* Eck characterises the processes in the suction centre of a vortex: "If $r = 0$ then $p = -\infty$ (in words: if the radius is 0, i.e. at the absolute centre of the vortex, then the pressure is minus infinitely great. The author). We are thus forced to acknowledge a negative pressure, that is a pressure less than in a vacuum (not to be confused with 'low pressure'). What does this mean? The pressure we have dealt with up to now was tension, i.e. a force directed to the centre of a body, and working positively. It will be easiest to imagine a negative pressure if we think of the theory of solids. Negative pressure is here none other than suctional tension. The same applies to liquids. But in general the liquid would disintegrate and vaporise before reaching this point."

A description by Rudolf Steiner, arising out of his spiritual scientific research, of the conditions at the centre of the sun is interesting in this connection:

"Imagine we have some kind of filled space—we will call it A and place a plus sign in front of it (+A). Now we can make the space emptier and emptier, whereby A gets smaller and smaller; but there is still something in the space, therefore we still use the + sign. We can imagine that it could be possible to create a space which is entirely empty of air, although this is not possible under earthly conditions because a space can only be made approximately empty. Were it possible, however, to make a space entirely void, it would contain nothing but space. Let us call it nought; the space has zero contents. Now we can do with the space as you can do with your purse. When you have filled your purse you can take out more and more, until at last there is nothing left in it. If then you still want to go on spending money, you cannot take out any more, but you can make debts. But if you have made debts there is less than nothing in your purse:

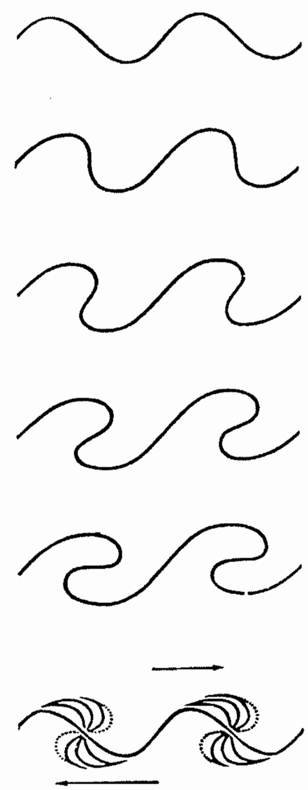
$$+A \qquad O \qquad -A$$

This then is how you can imagine the space—not only empty, but one might say sucked out, filled with less than nothing (—A). It is this kind of sucked out space—a space which is not only empty, but just the opposite of being filled with substance—that one must imagine the space to be which is taken up by the sun. Within the sun there is suction—not pressure, as in a gas-filled space, but suction. The sun is filled with negative materiality. I give this as an example to show that earthly laws cannot so simply be applied to cosmic regions. . . ." (From a lecture given on 24th June, 1921.)

In general we know water only according to its earthly laws. The build up of a vortex shows us that water is also governed by cosmic laws. We shall later go into this less familiar aspect of water in more detail.

The vortex is a moving part within a moving whole; it has its own rhythms, forms its own inner surfaces and is connected with distant cosmic surroundings. These qualities relate it to the realm of organic creation. It is a separate entity within a streaming whole, just as an organ in an organism is an individual entity, yet closely integrated with the whole through the flow of vital fluids. An organ is orientated in relation to the whole organism and also to the surrounding cosmos; yet it has its own rhythms and forms inner surfaces of its own.

All the different stages of the formation of a vortex, from the commencement of overlapping to the completed curling in of the layers of water, serve Nature in her formative creativity. During the course of development every organism and each of its organs must pass through a liquid state. The various possibilities of movement offered by the vortex present a direction along which an organ may develop before it eventually acquires its own individual nature and



The surface of contact between two currents curls over to form a vortex (after Bjerknes)

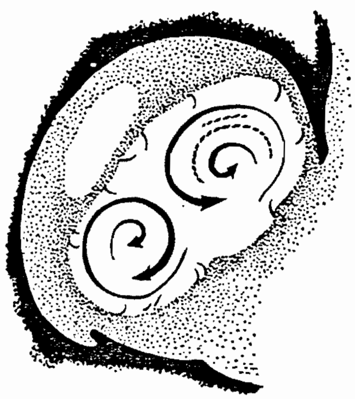
specialised function. The vortex in the water is completely unspecialised, and remains as pure movement at a primitive, undifferentiated stage of development. It is like an archetypal organ—an Ur-organ—having within it all potentialities of differentiation and formation. We can here see how the formative processes used by Nature for her various creations are pictured in the first place in the element of water as movements.

Some examples will elucidate this. First let us consider an example in which the vortex hardly appears as a form but is functionally present, guiding the formative process. In the embryo development

Development of the hypophysis in the sand lizard. The surrounding material curls in around the hypophysis as centre. Compare previous sketch (after Gawrilenko, simplified) of a species of lizard the formation of the hypophysis, an endocrine gland, commences at a certain point. Through certain growth processes in the head region of the embryo a kind of curling under takes place.

The above sketch shows the head end of the embryo and the position of the hypophysis. The two stages of the process are sufficient to show how the hollow at the place in question deepens and the curling in of the head region becomes more pronounced. If these separate stages are observed together we see how the whole head region is curved round the hypophysis as centre. The hypophysis here corresponds to the centre of the vortex itself, the surrounding material is "whirled in" around it. In this example the vortex form is not itself an organ, but as a process it dominates the whole development of the future organ.

If we take into consideration that the hypophysis is the organ which controls all growth, we may correctly presume that in the formative processes here described it is active as an invisible centre from which the growth processes *of all other organs* are guided. Taking also into account the connection between vortex movements and cosmic space, we find here the picture of a superior type of centre which creates other organs—a microcosmic world—around itself.



Instead of a complete system of semicircular canals the river-lamprey has one semicircular canal and two spiral cavities in which the liquid is kept circulating by cilia (after De Burlet)

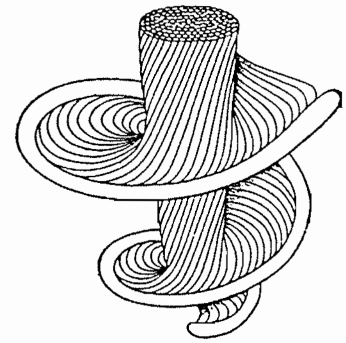
In the following example, a vortex movement in a liquid serves as an "organ" without solidifying into a solid form. In the river-lamprey we find a preliminary stage of the development of the semicircular canals in higher animals. Here, two out of the three semicircular canals are circling vortices in a liquid, each in its own cavity. They are set in motion by ciliated epithelia. If the interior of the cavities were to be filled with a dense substance, the membranous or bony semicircular canal would arise, as in the higher animals. In the river-lamprey the centre of the vortex is not yet filled in and the circulating liquid in the cavities is free to move. Like the semicircular canals, it serves as a sense organ and gives the animal a sensation of its position in space. What in the higher animals has solidified out into an organic form, is here still recognisable as a freely moving liquid in a vortex. The organ of the higher animal may be regarded as solidified movement; within it the movements of the liquid take place which lead to sense impressions.

The example which shows the vortex as an organic form at rest is the human cochlea, situated close to the semicircular canals. It is as though its dynamic force had entered into this most finely developed form. We shall return later to these processes in the inner ear itself.

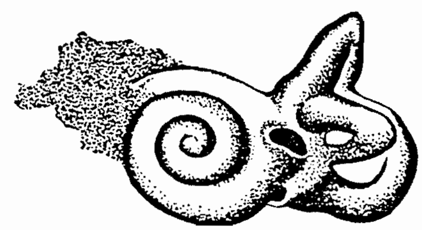
These three examples show different stages at which the vortex may reveal itself, ranging from an invisible creative dynamic principle to an organ in all its finest detail. All the intervening stages and manifold variations of the vortex formation can be discovered everywhere in nature.

The multitude of snails and shells, some spiral formations in the plant world and even the structure of many crystals speak of the vortex form and its dynamic force (Plates 42 and 43).

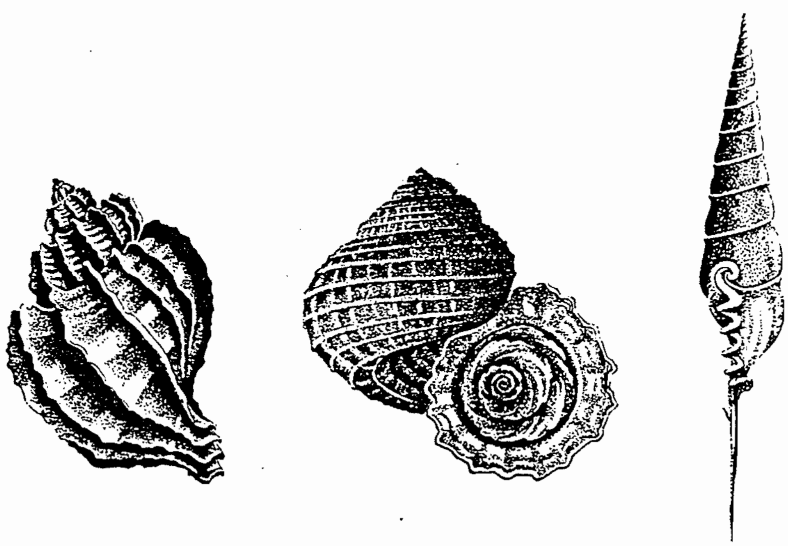
The form of the vortex, with its quality of creating a connection with the surrounding world, appears in the horns of many animals. Horns may often be regarded as delicate sense organs, which guide

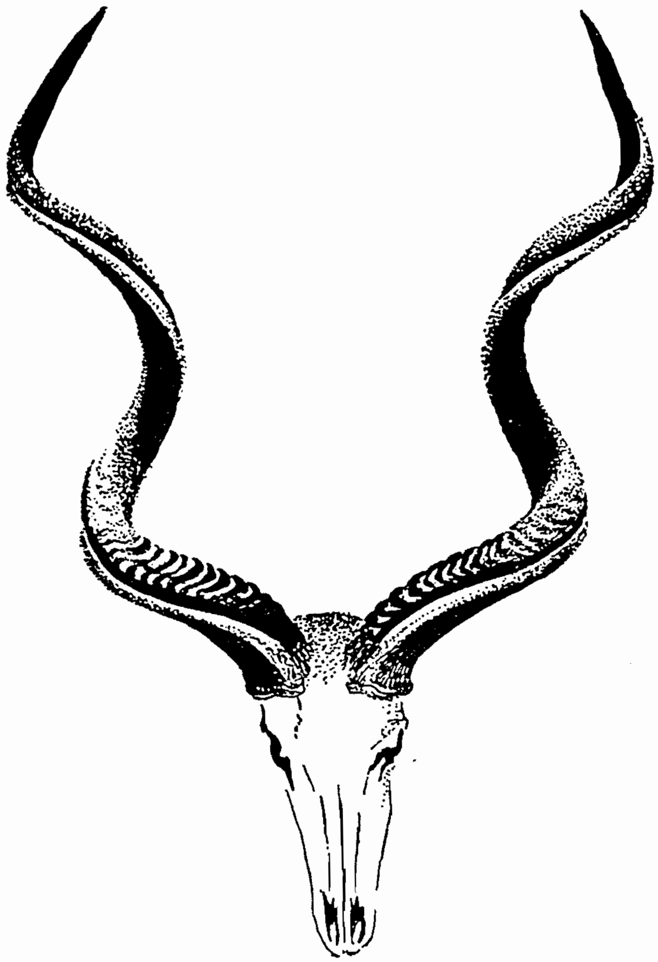


Fibres in the auditory nerve, arranged spirally just like a liquid vortex, as though picturing an invisible vortex of forces (after De Burlet)



Cochlea and semicircular canals in the human being (after Rauber-Kopsch)





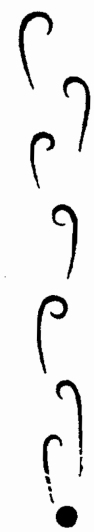
Horns of the African kudu antelope

the animal. The sketch shows the horns of the kudu, an African antelope. The twisting is clearly visible and also the axis round which the "vortex" spirals.

Here too the form of the vortex seems to hover invisibly over the growth processes, even before the horns are actually there, for they proceed along this spiral path with mathematical exactitude in their annual growth. It is significant that the axes of the two spiralling horns meet either in the nose or by the eyes or in their immediate vicinity, a fact which stresses the strong connection of the horns with sense perception and with the animal's sense of its surroundings. Furthermore, in structure the horn, like the water vortex, is finely laminated, layer upon layer.

A blade of grass or a twig dangling in the water causes a series of small vortices to form, which travel on downstream with the current. They are hardly visible, unless the sun shines through the clear water on to the bed of the stream, when they are projected, as already described, as small discs of shadow which move on in a regular pattern. On the surface of the water the vortices look like small hollows, in which a splinter of wood, or maybe a small leaf or some pollen, spins round. With the help of suitable additions to the water it is possible, just as with a single vortex, to make a train of vortices visible. Then the rhythmical pattern of the whole formation can be clearly seen (Plate 23).

United by a meander winding its way between them, the vortices alternate in corresponding pairs, one slightly ahead spinning one way and the other, behind, spinning the other way. If the stream flows slowly, only the meandering surface of contact arises. But the rhythmical train of vortices, formed out of the wavy rhythm and curling movement of the dividing surface, becomes more and more pronounced the faster the stream flows. This also explains the alternation which usually occurs in the pairs of vortices in a vortex train. In the moment of formation the two vortices lie opposite each other; only when the whole train has swirled into its final "stable" position do they lie alternately, one behind and still slightly to the side of its pair.



Rhythmical arrangement of vortices in water

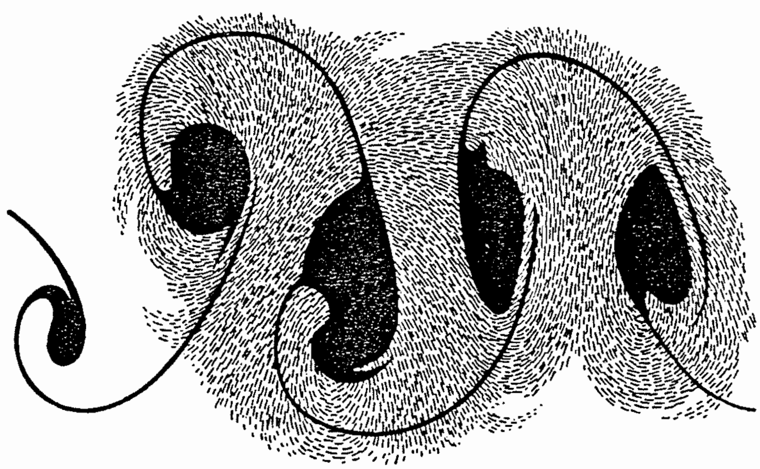
A similar process takes place if a small rod, held vertically, is drawn through still water. This method can be used for the study of trains of vortices, of which Plates 25–28 are examples. Plate 29 shows the preliminary wave formation caused by slow movement of the rod, and Plate 28 the completed curling process. Plates 25 and 27 demonstrate the differences in the vortex train caused by rods of different shapes and sizes. The rhythm in which the vortices follow one another varies according to the width of the rod: narrow rods cause short intervals between the vortices, wide rods cause longer intervals and therefore fewer vortices for a stretch of the same length, provided that the speed of the current or the movement of the rod is the same in all cases.

In order to make the vortex trains visible with such clarity, a viscous fluid was mixed with the water, slowing down the course of the movement and thus making the process easily discernible even to the naked eye. It is clear from Plates 25–28 that a train of vortices is a totality whose separate members are held together by strict rhythmical laws.

If one examines the whole field of motion of a train of vortices, for instance as in Plate 26, one notices that the single vortices are clearly separated from one another by a dividing line or surface. The vortices are here not fully formed, but the surrounding substance pushes into the space created by the moving rod, first from one side and then from the other, making visible the strict rhythm of vortex formation. The boundary of this advance can be clearly seen as a kind of "joint" where "ball and socket" lie opposite one another. Closer observation reveals furthermore a delicate structure passing straight across this "joint". The accompanying simplified sketch of the same picture may help to make this clear.

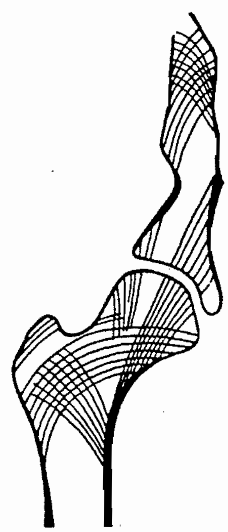
An examination of joint formations in man and animal shows that the fine spongy bone structures in the ends of the bones run straight towards the surfaces of the joint and continue on the other side of the gap as though there were no interruption.

Even the solid bones solidify originally out of a liquid state; therefore it is understandable that in their inner structure the same



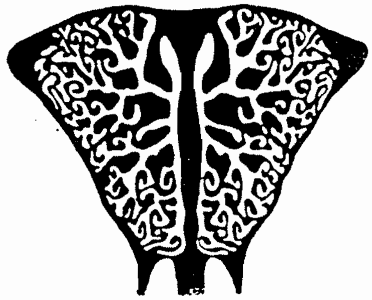
Absolute streamlines of the train of vortices in Plate 26

formations are found as in the vortex trains. In the one we see the structures in a state of flowing movement, in the other they are solidified into a fixed form, which then serves the flow of the static and dynamic forces in the limbs.
If water flows quickly over many small obstacles, such as pebbles, so many small trains of vortices are formed that they result in turbulence. Turbulence also arises if there is a great difference of speed in the water, say between the edge and the middle of a stream. The water is divided up by turbulence into countless circling inner surfaces. It is difficult to make the forms arising through turbulence clearly visible because the speeds are too great, but Plate 35 gives a rough impression of them.



Spongy bone structure in the human hip joint

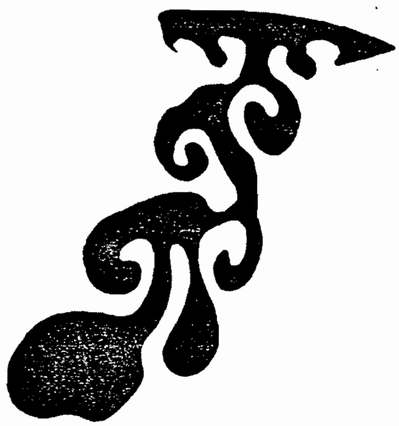
The forms to be seen in the bark and grain of many kinds of wood are like solidified images of turbulent currents in water (Plates 34, 36, 38). Not that the actual movement of the liquids in the wood is turbulent; rather it is as though these formations were the mark left by the invisible streaming of currents and forces in the plants.
Plate 34 shows the arrangement of knots in the trunk of a cypress tree. Plate 38 shows the trunk of a mountain oak, and Plate 36 the grain in the trunk of an olive tree.
In the paired arrangement of the vortices in a vortex train we have a principle of construction which occurs in the formation of paired organs throughout the animal and human kingdom. It is



The bony structures in the nose of the deer are formed like vortices, whereby the inner surface is greatly enlarged (from v. Frisch)

above all in the fluid state that the fundamental principles of moving form in living development are revealed, principles which underlie physical creation in the bodies of animal and man. How these formative possibilities come to be present in water can only be understood through living nature and the spiritual creative forces behind it. In the embryo development of man and animal paired formations appear at the very early stage of the original segmentation. Many organs, for example limbs, kidneys and some of the sense organs, manifest this principle of formation.

A particularly clear picture of a train of vortices in solidified form can be found in the organs of smell of certain animals, as for example the deer. It is as though the bony structure had solidified out of the liquid state in the form of a train of vortices. Large surfaces are thus created, past which the air can stream, giving the animal its very acute sense of smell. (We shall see later that these formations are also appropriate to the laws of moving air.) The accompanying sketches are of a plane section; in reality we are of course dealing with three dimensional structures which have more in common with the type of form we shall be dealing with in the next chapter.



Enlarged detail of the bony structure in the nose of the deer

A train of vortices is caused by a twig or something dangling in the water and parting it. If a small rod is drawn across the surface of still water, the vortices arrange themselves in a rhythmical pattern where the water is parted. Similarly, where two streams meet, a train of vortices forms at the surface of contact. A particular form of vortex is caused when a very narrow stream flows into still water. Then a dividing surface flows between two masses of still water, and like all dividing surfaces it makes rhythmical formations. The vortices which thus arise spin in the opposite direction to those which arise when flowing water encounters an obstacle. These two types of formation—vortices which arise when flowing water encounters an obstacle or those that arise when a thin stream flows from a small opening into still water—are opposite to one another; the one is the reverse of the other. The law we have already mentioned is valid here too. With a narrow stream, small intervals occur between vortices, with a wide stream, large ones. Of course, if the stream is excessively wide only the surfaces of contact between the stream and the still water will curve rhythmically and curl round, and not the whole flowing stream.

So we may summarise with the following comparison, always assuming a constant speed of flow:

Narrow obstacle:

many small vortices at short intervals.

Narrow stream:

many small vortices at short intervals (Plate 24).

Wide obstacle:

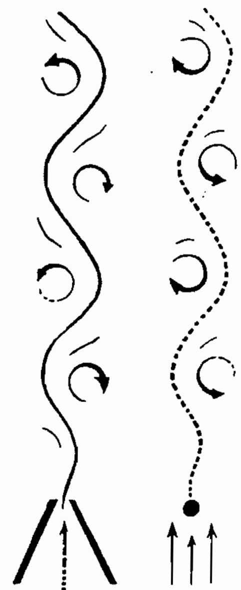
few large vortices at large intervals (Plate 26).

Wide stream:

few large vortices at large intervals.[1]

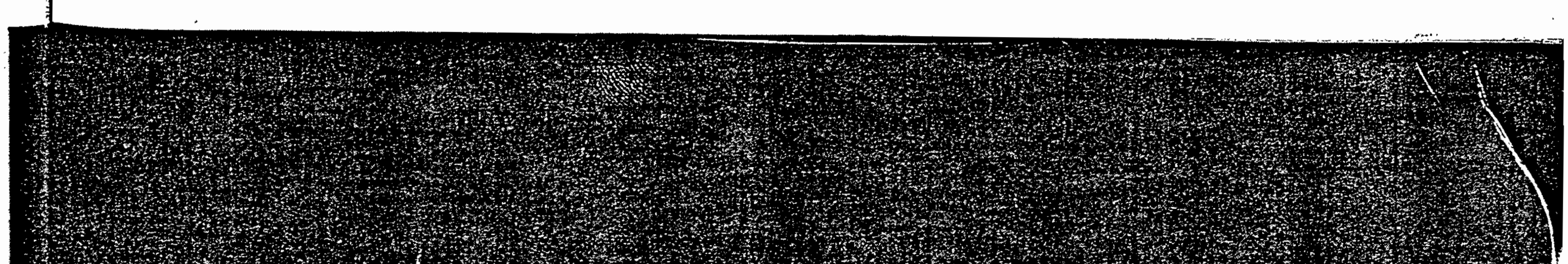
Up to this point we have dealt with the rhythmical processes of vortex formation at the *surface* of the water. But trains of vortices are *three dimensional* formations. Every vortex is—as has been shown—a funnel of downward suction. We must imagine every train of vortices to be a rhythmical sequence of such funnels, of greater or lesser depth.

[1] Strouhal's Law: $n \times \frac{d}{u} = \text{const.}$ n = frequency, d = thickness of rod, u = speed.



Comparison of two vortex trains from different causes: the direction in which vortices spin varies according to whether they are caused by an obstacle obstructing a stream of water or by a narrow stream of water entering still water through a small opening. The pattern of the vortices remains the same.

Vortex funnel



Vortices can also be formed below the surface of the water; they are then somewhat modified but their formation can be easily understood on the basis of what has already been described. Two examples from the abundance of experimental possibilities, which can of course always be found in nature as well, are as follows:

1. A coloured stream flows below the surface into still water from a thin pipe with a rectangular section.
2. Flowing water encounters a wide submerged obstacle.

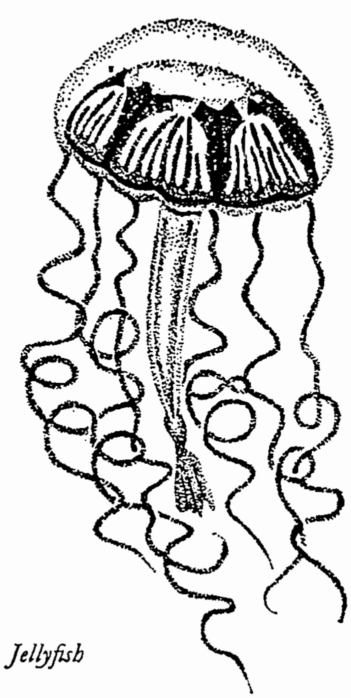
The stream from the pipe will describe in the still water a thin dividing surface, which becomes wavy and curls round. The form that arises (Plate 24) is very similar to that of a train of vortices on the surface of the water (Plate 28).

The water flowing round a wide obstacle will create a dividing surface along *all* submerged edges, that is along the whole outline of the obstacle, and this dividing surface, though itself consisting of water, will, like a sleeve, enclose an inner space. This dividing surface between an inner and an outer space undulates along its entire extent, contracting and expanding rhythmically. The expansions in the form of "bells" travel on beyond the obstacle with the current. A kind of pulsation is thus inscribed into the water as single quantities of water separate off, and the play of expansion and contraction becomes visible in the series of bell-like shapes (Plate 22). This expansion and contraction does not of course involve any increase or decrease in the density of the water. We nevertheless see how a pulsating rhythm is inscribed into the processes of flowing media. It arises as soon as currents meet under water, either in the wake of obstacles or when streams flow together from different directions.

To sum up we can say: behind a wide obstacle in flowing water a bell-shaped form arises, which is separated by a very clear dividing surface from the surrounding water, a form which itself consists of water and which travels onwards with the current. Something like an organic form is thus moulded in the uniform mass of the water, although there is absolutely no differentiation in substance. In other words we have here *the creation of form purely through movement*, inscribing itself into the water in rhythmical pulsation.

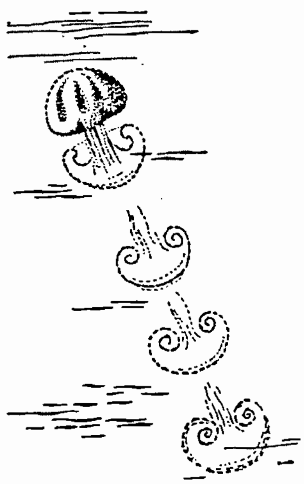
And now, instead of a constant stream from a submerged pipe, suppose only a short jet of liquid were to enter *still* water. It will form one single bell-like shape whose free edge curls outwards. As the bell travels, this edge rolls over further and further until the whole bell has turned inside out and curled into a ring (Plates 55–58). This rolling movement, which turns the form inside out, persists for a long time.

The ring consists of the most delicate spirally arranged lamelli, of which one can gain an impression by rolling up a cloth and then bending it round to form a ring. If this ring is now turned upon itself so that the layers at the inside move to the outside and then again to the inside, an approximate idea can be gained of the complicated pattern of movement in a ring that has arisen out of one of these "bells". As it travels the vortex-ring loses its circular form, and becomes "unstable" with excrescences on its circumference that make it look star-shaped (Plate 56). (The number of excrescences depends on the speed at which the original jet issues into the still water; a fast jet causes more bulges than a slow one.) The inner part of the ring has very complicated structures, which become partly visible if it collides with a flat surface held in its path. Experimentally this is possible for instance by letting the ring rise from below towards the surface of the water, with which it collides, scattering into a star-like shape (Plate 58). A similar thing happens when a drop falls into the surface of a liquid (Plate 59). This process can be used to demonstrate qualitative differences in liquids, for under the same conditions different fluids or liquid solutions will behave differently and produce varied star-like patterns.



Jellyfish

By its pulsating method of propulsion the jellyfish causes mirror images of itself to arise in the water (diagrammatic sketch)



The process just described, when a jet of water moves into a still liquid, is not just an abstract idea, but can be found in the habits of many water creatures, for instance jellyfish. The jellyfish, a creature consisting of up to 99 per cent water, is itself an expression of the laws of movement in fluids. Even its outer shape is noticeably similar to vortex-bells, and so is its method of propulsion. The jellyfish progresses through the water by ejecting water from its body cavity, thus being driven forward by the backward thrust. Each jet of water takes on a bell-like shape, like the jellyfish itself but in reverse. It is like a mirror image of the jellyfish, moving in the opposite direction. With every jet of liquid it ejects, the jellyfish makes a mould of itself in the water, but only momentarily, for the form dissolves again. Repeating its jets, the jellyfish creates a whole sequence of bell-shaped forms, as though embodying a kind of "language" into the water, recreating itself again and again as a transient, fleeting form.

Particularly in the realm of jellyfish and medusae it is as though the water were to become partly independent, preparing a kind of "shell" for a sentient animal.

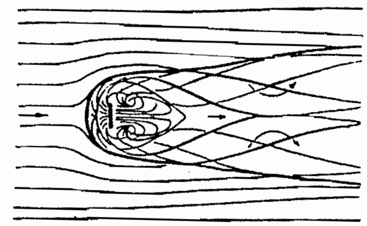
Many of the movements and forms we have already seen in water reappear as body and movement in the lower water animals. As well as jellyfish one need only think of sea-stars, sea-urchins, snails and many shells (Plates 42, 43).

"The resting state originates in movement"

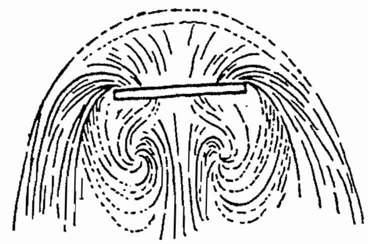
> There is no doubt that our
> body is a moulded river.
> (Novalis, Aphorisms)

We have repeatedly seen how surfaces—both inner and outer ones—are very significant regions in the water, where rhythmical and formative processes take place. It is in the creation of surfaces, when an inner region is divided off from an outer one, that all structural formation comes about. This takes place through the interaction of the forces in both regions. In the following paragraphs we shall be turning our attention to this important principle.

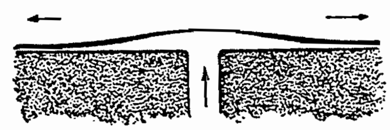
Even a stone protruding from a stream gives rise to a definite formative boundary-surface in the water, which maintains itself as a stationary form in the midst of the streaming water.
As an obstacle in the stream, the stone offers resistance to the water flowing towards it. The water gives way on both sides and meets again a little further downstream. Behind the stone, downstream, a fairly calm backwater zone can be observed, separated by a clear dividing line (dividing surface) from the faster flowing water. This dividing surface is the result of the interaction of two forces: the force of the moving water and the force of resistance of the immobile, heavy stone. Two regions arise: an outer one, where the water is flowing past fairly fast, and an inner space in which the water flows more slowly, making manifold cross currents and circular motions.
Now let us imagine that we remove the stone, but maintain the force of resistance it makes against the current by sending in a stream of water from the place where it had lain. The following is a simplified description of an experiment along these lines. From the opening of a pipe in the bed of a stream or a canal, water enters the general current. It offers a resistance to the current, which has to give way. Thus, as before with the stone, a boundary surface arises which makes a *stationary* form within the water, surrounded by flowing liquid.—It is by no means only a solid obstacle in the path of a stream which creates a stationary form in the water. Such a form can come about through forces of movement in the midst of the flowing water itself. For example, a spring in its basin throws up from below a small circular mound of water. It gushes up out of the ground and then spreads out, being constantly replenished by new water. Similarly, in an artificial spring from a pipe in the ground water will surge up in a circular form, the force of the flow lessening as the water spreads away from the source. If there were a slope the water would all flow away in that one direction. Now if a direct current is made to flow over this spring, it will meet with resistance where the water of the spring comes up towards it. There will be a region where the forces of both streams balance each other out. Here, the water of the stream will not be able to penetrate the region of the spring nor will the spring water be able to push upstream. The oncoming water of the direct current avoids this meeting place and flows away sideways. Then, meeting the water flowing outwards from the spring, it is pushed out even further. The result of the interplay of the two currents is a boundary region, in which their



If water flows round a fixed plate, a dividing surface arises in the water (diagram after Kopp)



Stream-lines engraved by the water itself into the bed of a stream behind an obstructing plate (after Kopp)



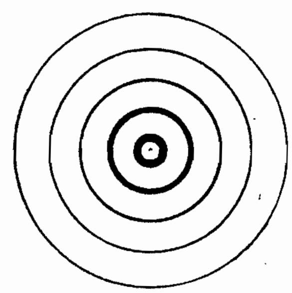
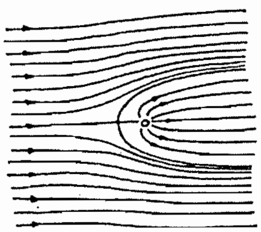
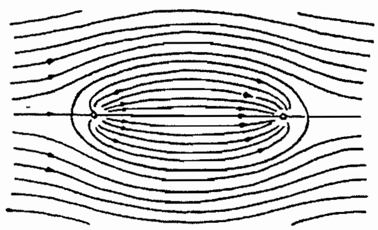


Diagram of a source, cross-section and seen from above



A dividing surface develops in the water between the flow of a direct current and a source



An enclosed dividing surface arises in the interplay of a source, a sink and a direct current

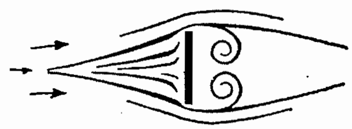
forces are held in balance. This boundary form simply indicates the moment of balance between the forces of the spring and those of the stream; it divides off the regions of the two currents according to their strength. If the spring grows stronger the boundary form opens out, if it weakens, the current of the stream overpowers the form and it shrinks. Dividing lines and surfaces of this kind are forms of balance between the forces of different regions; they respond with expanding and contracting movements as sensitively as do the scales of a balance to the smallest changes.

Now let us add to this arrangement a little further downstream a place where water is sucked away, for instance a drain pipe, making a "sink" in the bed of the canal. As was the case with the spring, the forces of suction from the "sink" will enter into relationship with the forces of the general current—but with the opposite effect, so that the boundary surface will close behind the outlet. In this way an enclosed inner space is divided off from an outer space. A small change in the size of the outlet will cause the boundary to expand or contract, so that the form as a whole becomes plumper or slimmer. It is easy to imagine that such boundary surfaces in flowing water are exceedingly delicate indicators of the smallest changes in the interplay of forces in the water. As quiescent forms they are the picture of these forces in the midst of the moving water and they react like the most delicate sense organs to any inner or outer change. Every source or sink added to this arrangement causes the form to bulge out or contract, and we see that the formative possibilities in such varying currents are infinite.

The outline of any figure can be created by the interplay of currents, surging outward, flowing parallel or contracting towards an outlet. On the other hand, the forms of any obstacles in a current of water have the same effect, though in reverse, as a corresponding system of sources and sinks by which they might be replaced. It is easy to imagine that the spiralling form of a vortex might also be used together with other currents to create quite specific boundary surfaces.

The boundary surface reacts like a sense organ to any change of pressure (change of speed) inside or outside the space enclosed by it. Isaachsen describes a case in point; water flows round a plate which acts as a dam, creating a backwater region, which is enclosed by a sensitive boundary surface. He says, "It is as though in the backwater there is an organ, which measures and regulates the pressure, and this is indeed the case. . . . The tip of the backwater is the "feeler", the organ that measures and regulates, constantly registering the pressure of the speed of flow."

So boundary surfaces arise through the confluence of currents from different directions and picture the states of balance of the forces at work in water. They can make enclosed forms which lie *quiescent* amid *flowing* movement and respond with expansion or contraction to any delicate change in the currents. They really are like delicate sense organs.



Water flowing round an obstructing plate or slab (after Isaachsen)

Is it not a striking phenomenon that in the midst of flowing movement forms arise, not through any differentiation in substance, but simply through the interplay of currents and their forces? This points to a formative principle based on the interplay of movements rather than on material substance. It is movement that takes hold of the substance and moulds it. Only through a true observation of these facts is it possible to approach an understanding of the processes which lead to the creation of forms in the embryo; neither in matter alone, nor in the process of cell-division is there a basis for understanding what is happening in this sphere.

Flowing processes are active in the growth of all organisms. Through faster growth some parts protrude, others are held back through a suspension of growth or even dissolved again. In all stages of embryonic development there is an interplay between forces of welling outflow and suctional inflow, by which the respective shapes arise. We see it in the very first stages of embryonic development; the swelling enlargement of the fertilised ovum and the subsequent intucking in gastrulation.[1] In the course of the

[1] From what has been said it will be clear that we are concerned here with a general principle of formation, and are not considering the differences in the embryonic development of the various species.

development of the embryo these principles, acting as formative processes, can be found again and again. They are superior to, and regulate the mere division of cells. But even this superior principle of outflow and inflow, with its streaming movements and temporal sequences, is in its turn the tool of the creative idea that lies behind it. We come across this principle in all conceivable variations in embryonic development. A multitude of sources, sinks and currents work together to create the living form. This interplay is like the diversity of an orchestra with its instruments, that have their entries and their rests and are moulded into a *single* "body of sound" by an invisible conductor according to a strictly systematic score. Often outflowing currents are active—for instance when the optic vesicle is formed—which, after a time cease and pass on the theme to another part of the development. The score and its entries remain of course in a region superior to this process, from which they penetrate the impressionable liquid substance and cause it to take on a harmonious form.

A *universal* and *harmonious* concord of all possibilities will bring forth the human form. Emphasis on the development of certain details will lead rather to animal formations with their specialised one-sidedness. One may think for instance of the immoderate protuberance of the bill of a crane compared with the moderate proportions of the mouth of the human being. But of course it is just such one-sided features that bring to expression the nature of the respective animals. (See *Man and Animal*, by Poppelbaum.)

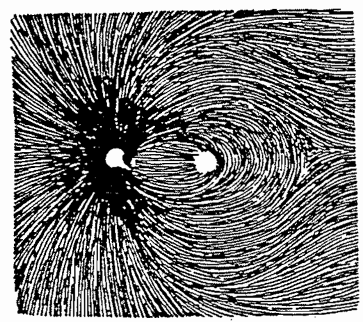
We shall not go generally into the details of embryology, assuming that they are common knowledge, but restrict ourselves to one example, the development of the eye, in which such varying movements work together to form a sense organ.

First the small bulge of the optic vesicle grows out of the forebrain. The optic vesicle touches the ectoderm from the inside and this in turn becomes invaginated at this point towards the optic vesicle and

The development of the human eye

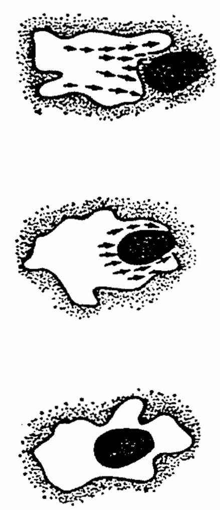
thickens to form the lense. The optic vesicle is squashed in by it and becomes cupped around it. The lense—moving inwards—then loses contact with the surface and becomes enclosed by the newly formed optic cup.

It can also be seen how the retina in the human being has arisen out of the principles of source and sink. The point where the optic nerve leaves the eye is like the outlet—the sink—in a stream of water, and the neighbouring *fovea centralis* like a spring. The way the two work together is clearly recognisable in the diagram of the "field of forces" of the nerve fibres in the retina.

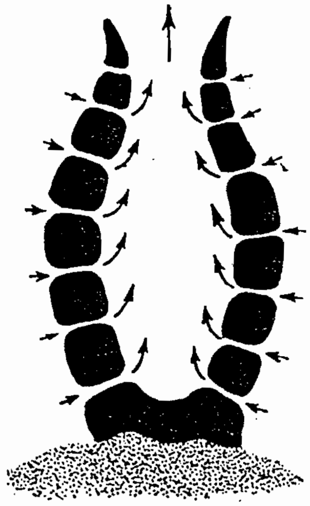


Nerve fibres in the retina around the fovea centralis and the point of exit of the optic nerve (after v. Michel)

Even in water the surfaces of the forms that are created by flowing movements are unbelievably sensitive. But it is a sensitivity which is not based on any nervous system, which arises purely out of the interplay of forces and is not to be understood from the aspect of the substance. How delicate then must a skin be, which constitutes a boundary surface which is also differentiated in substance! Surely here Nature reveals one of her secrets by anticipating sensitivity in flowing movement without needing a nervous system! Does she not actually incorporate in the substance of the nerve-sense organs in living creatures the sensitivity already present as a function in fluids? At a primitive level the amoeba, with the sensitive surface of its body, is an example of the principles of source and sink. It does not solidify into a fixed form but remains in the flowing, constantly changing fluid state of embryonic processes. At will it can thrust out a limb, now here, now there, by pushing out its watery body, retracting it again by suction and thrusting it out again elsewhere. It responds to every stimulation from outside through a change in its surface form. It either flows towards the source of stimulation, thrusting out a limb of its body liquid in this direction, or it retreats,



An amoeba "engulfs" and absorbs its prey



Currents of outflow and inflow as water passes through a sponge (after Kühn)

drawing its body liquid away. Here is a first gentle hint of how animal instinct expresses itself simply in living, flowing substance. The most varied versions of these possibilities may be found among the unicellular water animals. For instance some creatures are able to thrust out a limb and fix it for a while and later to transform it back into a liquid state again. They can make free use of the delicate change from gel to sol, making the form of their bodies changeable or permanent. Indeed, they revel in their true element in this unstable, sensitive "border region".

Other creatures mould their bodies as though to form only the shell for these processes of sink and source. With the sponge, water streams into the inside through narrow channels on the surface (sink). This water collects in the centre of the creature and passes out again in a concentrated stream, like a spring. In the course of this process the particles of food in the water are absorbed. The stronger the stream issuing forth, the stronger the suction (sink) inwards, and vice versa. The visible form of the sponge grows out of the relationship between the two.

The most simple form of spring, one with a pulsating activity, has already been described in connection with the jellyfish. This creature ejects a rhythmical series of jets into the surrounding water, imprinting its own image upon the water. The form of the jellyfish is no more than an expression of the simple pulsating movement in a spring, transformed through the resistance of the surrounding water. All these are archetypal, creative movements, working in accord; they have been described separately simply for the sake of greater clarity. But Nature does reveal her secrets at particular moments; some of her archetypal movements she reveals separately by densifying them to clothe a living creature.

And if Nature creates creatures in which she reveals *one* of her creative movements, she also creates *one* living creature in whom all archetypal movements stream together: the human being. . . . "The human being as we see him is a completed form. But this form has been created out of movement. It has arisen from those primeval forms which were continually taking shape and passing away again. Movement does not proceed from quiescence; on the contrary, that which is in a state of rest originates in movement." (From a lecture given by Rudolf Steiner on 24th June, 1924.)