THE LIVING PLANT

AND THE SCIENCE OF

PHYSICAL AND ETHEREAL SPACES

A Study of the "Metamorphosis of Plants" in the Light of Modern Geometry and Morphology

by

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NOTE: Asterisks in the main text, in the absence of a footnote, refer to Notes in the Appendix; the latter are numbered according to the Section to which they refer.

FOREWORD

by GEORGE ADAMS

THIS book is an outcome of researches bringing together realms of knowledge which in the specialization of the sciences have hitherto been far apart. In method and idea it is in near relation, as we hope to shew, to the scientific work of Goethe, and the Bicentenary Celebrations have provided the immediate occasion for its publication in the present form. As part of a scientific exhibition bearing on Goethe's work, a series of coloured drawings by Olive Whicher are being shown, containing in picture-form what we have here tried to set down in words; the book has been written in this connection. It has, alas, been necessary to produce it very quickly and without illustrations. We hope this is only the forerunner of an edition in which the drawings, or a sufficient number of them, can be included. Theory and phenomenon are here brought very close together; thus an artistic form becomes the natural way to express the scientific concepts.

The concept of "Ethereal" or "Negative-Euclidean" Space as a new and fundamental factor in the theory of life and living form was, I believe, enunciated for the first time in 1933 in an Essay which I contributed to the periodical *Natura,* issued by the late Dr. Ita Wegman for the Medical Section of the Goetheanum, Dornach, Switzerland. An English edition appeared in the same year, under the title "Physical and Ethereal Spaces."

Mathematicians had, it is true, entertained this idea from time to time among the various possible non-Euclidean spaces, but it had never been conceived, so far as I am aware, as an essential aid to an understanding of the real world. It was Rudolf Steiner (1861—1925) who in the later period of his life drew the attention of scientists to the important tasks which lay in this direction. During my University studies I had been impressed by what Sir F. G. Donnan has described as the then prevailing thermodynamic phase in the development of Chemistry, with which the names of Willard Gibbs, J. H. van't Hoff, Wilhelm Ostwald and others are connected. Ostwald had been insisting on a more purely phenomenological approach. The Theory of Relativity was affecting the very foundations of physical science. Trying to delve more deeply into the prevailing theories of physical forces and fields of force, I was led to Projective Geometry. While studying some of the earlier writings of A. N. Whitehead, I became convinced that the profound ideas of this science—above all, the fundamental polar relations known as the "Principle of Duality"—were destined to have a transforming effect on the whole realm of Natural Science. Thus when I heard of Rudolf Steiner's indications my own thoughts and hopes were already going in a like direction.

At the time when I wrote the above-mentioned Essay I was collaborating with the late Dr. E. Vreede in the Mathematical-Astronomical Section of the Goetheanum. We published the volume *Strahlende Weltgestaltung,* in which I tried to shew the fundamental bearing of Projective Geometry on Natural Science generally, also its close relation to Goethe's way of thought and its importance for a spiritual world-outlook.

The concept of Negative-Euclidean Space has since been independently put forward by the Swiss mathematician Prof. Louis Locher of Winterthur, who calls this form of geometry "Polar-Euclidean" and devotes to it a section of his text-book on Projective Geometry, published by Orell Fuessli, Zurich, 1940. In the conviction that this form of space will soon be playing an important part in Natural Science, Prof. Locher too acknowledges his indebtedness to Rudolf Steiner.

My collaboration with Olive Whicher began about fourteen years ago. In trying to awaken and impart the idea of interpenetrating polar spaces, including a form of space in which the plane and not the point is primary, diagrammatic figures are not enough. Olive Whicher developed the technique of conveying the geometrical truths in coloured drawings in which the polar qualities of space find true expression, appealing directly to the imagination. She was able to imbue her pictures with an ever deeper understanding of the scientific principles involved, and the pictures themselves became an awakener of new understanding. We went on working on these lines when the vicissitudes of recent years permitted.

In course of time the ideas which had been living in a more theoretic form were re-awakened in direct perception of surrounding Nature. It was in the spring of 1947 that I first discerned, while looking at the growing and unfolding shoots, the presence of an ethereal focus in the hollow space *above* the growing-point. From this moment onward we elaborated this botanical work together. In contemplation of the growing plants, in seeking to express the truth in thought and word and picture, the ideas have developed to their present form. This volume represents a momentary cross-section of a continuing work, which, like the plant it tells of, grows and unfolds. It also sheds its light on kindred realms which we have not included here, such for example as the nature of the insect world, nearly related as it is to the world of plants.

We have tried to express these things in such a way that the general reader will not have undue difficulty in following the thought-pictures. The life of the plant, described as all men can see it, goes before; the geometry follows after. Our aim has been neither to take too much geometry for granted nor to overload the book with elementary digressions whose proper place is in a textbook. Technical details, such as the imaginary circle and cone, are dealt with briefly and in a more mathematical form in the Appendix. Where geometrical pictures should have been included, pending an illustrated edition we have given brief descriptions, so that the reader may imagine them or sketch them for himself.

We are well aware of the one-sidedly morphological character of this work and of the many phenomena we have not dealt with even within our chosen field. If the fundamental idea proves true, it will in some way be applicable to the cell-nucleus and the processes of cell-division; this is a realm we have for the moment left untouched. The book itself explains why we believe that the understanding of the microscopically small may perhaps follow rather than precede the other. Nor do we think our explanations cut across the many wonderful discoveries of recent times, on growth-hormones for example and other aspects of physiology and bio-chemistry. The same phenomena can be approached on different levels. In time the morphology of the living plant will also shed its light on the purely chemical domain.

Among the many friends who have helped us we wish to mention two who died before the work had reached its present stage. I have already written of Dr. E. Vreede with whom it was my privilege to collaborate, beginning over twenty years ago. She was deeply united with the whole aim and direction of this work and understood its great significance for the future. We also remember the help and encouragement we received from Dr. E. Kolisko, a scientist of unusually wide range and one of the most inspiring of morphologists.

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Chapter I

INTRODUCTION

Goethe's 'Metamorphosis of Plants' and the Present Work

THE work that is here put forward—during the Bicentenary Year 1949—claims to be inwardly related to Goethe's botanical researches and to his whole scientific outlook. Yet it is new in many ways and involves scientific premisses that were not given in his time. It is therefore incumbent on us to say why and how we think this work is in his spirit, although admittedly it goes beyond him in directions that will yet have to be tried and tested.

It may cause some surprise that a largely geometrical approach should claim affinity with Goethe's work. Yet as some modern authors have recognized, there was far more of the mathematical in Goethe's thinking than might at first appear. Mathematics too has gone a long way since Goethe's time and we are nearer today to an appreciation of the qualitative and form-creative as against the merely quantitative aspect of this science. It is this qualitative aspect which will here emerge.

In two directions we believe our work to be a true continuation—perhaps even *the* necessary continuation for our time—of Goethe's morphological researches. First as to the prevailing method; and second, as to the essential content of the botanical and other underlying notions.

2. Goethe's Scientific Method. Goethe comes nearest to avowing the implicit theory and method of his scientific work in some of the *Prose Aphorisms* (Sprüche in Prosa); in the remarkable essay *Experiment as Mediator between Object and Subject;* and in the history of his botanical researches—notably the chapters *Happy Encounter* and *Perceptive Judgment* (Anschauende Urteilskraft)—in the later editions of the *Metamorphosis.* He did not reflect much on his own theory of knowledge; systematic philosophy was not his line. Yet a true method, a consistent theory of knowledge underlay his work. The first and unsurpassed account of this theory and method is contained in Rudolf Steiner's early writings.*

Goethe believed that the true Theory is contained in the Phenomenon. The phenomena our senses see do not deceive us; they are not unlike the ideal reality which brings them forth. As the Greek origin of the word implies, the Theory is the true *seeing* of the thing—the insight that should come with healthy sight. Yet man is so constituted that he does not really see unless he meets what he sees with spiritual activity on his own part.

It then becomes the rôle of thought to interpret the language of phenomena. If what our thinking reveals is *in* the phenomena the senses see,—so that, enlightened by thought, we feel that we are seeing with new-awakened eyes—then will our thinking have been true. Scientific thought therefore is not to lead us away from the phenomena into some remote construction from which the thing perceived derives by elaborate causation. It is to give us the faculty—latent but unawakened in the merely passive mind—to read in the phenomena, so that the chaos of detail becomes articulate language.

If this be true, the wisest outcome of our science will bring us ever nearer to a fresh and childlike seeing. It will be a literal meeting of the extremes of childlikeness and erudition. Nor is the meeting-ground entirely remote from the experience of cultured man, even with Science incomplete as it still is. Something of childlike discovery persists throughout our life and is ever re-awakened,—nowhere more than in the seeing of the plant-world. This is the rejuvenation without which life would be grey indeed. Where it is more than usually vivid, we have the insight of the poet and the artist—often the

forerunners of Science. This is indeed a truism on which scholars far too easily fall back in Goethe's case, neglecting the detailed value of his researches.

The work here shewn is true to Goethe's method in that the ideal insight we bring forward answers to what human beings see and love in the realm of higher plants. We shall therefore begin, in Chapter II, by describing what is seen, and only then go on to the ideal and theoretical approach.

Leading Ideas in the 'Metamorphosis of Plants'

In the description Goethe gives of the " ideal plant"—*Urpflanze*—there are certain fundamental elements of insight. These, we believe, are themselves interpreted and carried further in the light of the ideas here put forward. The following are the main elements we have in mind: —

3. Unfolding of an Ideal Type. A living form is seen as the progressive unfoldment and manifold revelation of the ideal Archetype by which it lives. This is implied in the very word "Metamorphosis" as used by Goethe. The scientific explanation therefore takes the form, not of a logical piecing together of " natural laws " following causes and effects as in the accepted form of inorganic Science, but of *describing* how the ideal principle, once recognized, unfolds and brings forth the successive forms and changes from form to form.

" For the type of explanation based on cause and effect," says Agnes Arber, " Goethe substituted a process that can be described only by the untranslatable German word, ' Darstellung,' which may be defined, approximately, as the demonstration or representation of an object, brought into relation with others in such a way that its significance is revealed."

The new Geometry which we shall apply here tends to the same descriptive method; hence at least one eminent English mathematician—Arthur Cayley—called it "Descriptive Geometry" pure and simple.* Unfortunately most of the existing text-books, holding perhaps inevitably to the traditional method—a logical chain of discrete axioms and theorems,—tend thereby to conceal the essential beauty of the new Geometry and make it seem more abstruse than it really is. Goethe's conception of an ideal Type—to be identified with none of the particular forms in which it finds expression, and yet made manifest in all of them —answers exactly to one of the main thought-processes of the new Geometry. There is an " elective affinity " between the Goethean morphology and this other branch of modern thought, which makes it possible—and very fruitful—to bring the two sciences together.

4. Organic Relation of Part and Whole,—the " holistic " strain in Goethe's thinking. In the part, the virtue of the whole is contained. For Goethe this became immediate aesthetic insight, and so it is for many a biologist in gifted moments. Others who divine this truth have put it forward in various philosophic forms. The fundamental notions we shall here bring forward will relate this principle to one of the deepest and clearest of scientific discoveries in recent times—the geometrical " Principle of Duality " (see Chapter III, notably ¶ 22—24). For living spatial forms this mutual relationship of part and whole will prove the natural outcome of a profound structural principle of Space as such.

5. The Leaf as Fundamental Organ of the Plant. Though Goethe does not indentify the " Archetypal Leaf " as an ideal Type with any one of the many forms in which it is revealed, yet the most characteristic of them is undoubtedly the foliage-leaf to which it owes its name. Again on very fundamental grounds, we shall be led to understand why and how the " ideal plant " manifests itself in an expanded surface-form such as the typical leaf. Indeed we venture to suggest that the *planar* aspect of spatial form, revealed in the myriad leaves of plants around us, is Nature's polar counterpart

to the tendency of *pointwise* integration—and also disintegration—which belongs to inorganic matter and of which our atomic theories and discoveries are but an ultimate expression.

At the same time, modern Geometry will give us deeper insight into the organic pairing of leaf and "eye" (and the analogy of eye and seed), and also into the relation—passed over rather too briefly by Goethe—of the "archetypal leaf" to the more linear expression of the plant in stem and root.

6. Expansion and Contraction. Goethe sees the life of the higher plant as a threefold rhythm of expansion and contraction. First, the expansion from the germinating seed into the leaf and leaf-bearing shoot, and the contraction of the upper leaves into involcure, calyx, flower-bearing bract. Second, the expansion into coloured perianth and petals, with the contraction into ovary and stamens. Third, the expansion of the fertilized ovary into the fruit, and the supreme contraction of all—that of the plant's potential essence into the seed.

To the attentive reader of the *Metamorphosis* it must be evident that far more is here intended than the mere ascertainment of an alternate increase and lessening in volume. "Expansion and Contraction" is an ideal process, so much so that the life of plants, when understood in this way, can change our outlook on the spatial Universe, shedding a deeper light on what would otherwise be trivial ideas of size. The geometrical ideas we introduce help us to realize more consciously what this ideal process is.

7. Polarity; Enhancement. While these ideas do not play quite so explicit a part in Goethe's Botany as in his Theory of Colour, yet they are deeply implicit in his conceptions of Expansion and Contraction and of the gradual refinement of the plant as it ascends from cotyledon-level to the fuller manifestation of its ideal nature in the flower. In his Introduction (1807) Goethe writes: "The 'up-and-down'—'below, above'—is the first thing that strikes us when we contemplate the vegetable type of life. Down goes the root, the affinity of which is to the Earth, to realms of moisture and darkness; while up towards the Heavens and into the light and air strives the stem, the trunk, or whatsoever else is there to indicate its place."* This morphological polarity of the higher plant is to this day one of the most insistent and most puzzling of phenomena; it plays a fundamental part in the new ideas we shall here bring forward, in very near relation, as it will prove, to the ideal polarity—Light and Darkness—of Goethe's Physics.

8. Vertical and Spiral Tendencies. In 1831, towards the end of his life, Goethe wrote the essay *On the Spiral Tendency of Vegetation,* the leading ideas of which had been to a great extent implicit in his earlier work. What he describes as the "spiral" in contrast to the "vertical" tendency may also be thought of as the peripheral principle. Spiral phenomena of growth and leaf-arrangement (phyllotaxis) appear as a natural outcome of these two components, with the one or other predominating.

Goethe's description of the interplay between the vertical principle revealed in the upright stem and the peripheral in the multiplication of leaves and budding side-shoots is of great sublety, shewing again how he conceives any prevailing polarity in an organic way. Where an ideal polarity is at work, each of the two contrasting elements comes to expression within the realm of the other; we have to go deeper to recognize them in their functions. The vertical, says Goethe, is like a "spiritual staff,"—a law-giving power in the midst. To the peripheral or spiral tendency he ascribes the power of nutrition and proliferating increase. Each leaf and eye, he says in an earlier writing (studying some examples of uncontrolled and monstrous growth) has in itself the right to become a tree; that they are held in check, is due to the "all-ruling health and soundness of the stem or trunk." Formless proliferations are the outcome when this power flags or is overwhelmed by excess of nutriment.*

In the morphological work here shewn the relation of vertical, spiral and peripheral principles will play a leading part; our geometrical treatment will shed a new and unexpected light upon it and notably on Goethe's concept of a "spiritual staff." Now there is also a very simple aspect to this relation, the deep significance of which may even be overlooked because it seems too obvious and trivial. As it provides a common ground between our own and many earlier studies in plant morphology, we will draw attention to it here.

9. The Spatial Matrix of Plant Life. Every tangible entity in Nature is in the three-dimensional world; if then a living body has any regularity of pattern it will make manifest not only its own particular nature but also some aspect of the structure of space as such. If we now ask, to what aspect of spatial structure does the higher plant mainly belong, we are led again to Goethe's vertical and peripheral relation.

The crystal-mineral world reveals two great types of spatial form. One is the triaxial, that is to say, typically three dimensional. Three axes meet in any given centre. They may be at right angles and of equal length and function, as in the "cubical" system; crystals of this kind will be most simply related to the prevailing laws of universal space and movement. Or the three axes may be of diverse length and even with their angles diversely inclined; other crystal systems are the outcome. But side by side with this there is a different type,—the hexagonal and trigonal. Here there is *one* main axis, perpendicular to which there is a plane—or sequence of parallel planes—containing not two but three further axes, at equal angles of 60° to one-another. Rock-crystal or quartz—crystallized silica—is a typical example.

The type of space here shewn, with its single axis and series of planes at right angles thereto, is archetypally related to the rotational and spiral forms of movement (rotation about the single axis, which, if translation along the axis is added, will produce a screw-spiral movement). It is symptomatic that the crystal of silica—one of the most universal of earthly substances—does actually beget this form of movement, for when polarized light is passed through it in the axial direction, the plane of polarization is spirally rotated. Moreover, as among climbing plants there are those that form left-handed spirals and others right-handed, so there are left- and right-handed quartz crystals.

It is surely significant that the plant belongs to this axial, rotational form of space. Think for a moment of the most undifferentiated spatial form—the sphere. Though it is deeply related to the three-dimensional structure of space, no particular axial directions are singled out; it does not matter in what directions we begin if, say, we wish to circumscribe a cube about it. But as soon as we bring the sphere into rotation, if only for a single moment, we must rotate it about a *particular* axis; immediately, as on a geographical globe, this axis and the planes of latitude at right angles to it emerge, governing the whole structure.

Our Universe abounds in rotational forms of movement; for the Earth these find expression in the daily, yearly and other periodic rhythms and in the apparent circling movements of the heavenly bodies around us. The plant, of all earthly creatures the one that most expands towards the Universe and takes its life and time from thence, belongs precisely to this form of space. The significance of this is all the more enhanced when with the help of modern Geometry our concept of the underlying form is deepened.

The normal plant is rooted in the earth; its onlymovements are the slow and silent ones of growth. Yet through the days and nights and seasons it is ever surrounded by the circling movements of the moon and planets, of the sun and stars. It rises towards the zenith and unfolds its leaves to the horizon, mostly in regular and spiral sequence. It is at rest amid an ocean of circling movements; only the mathematical regularity of its pattern and form of growth is of the circling and spiral type. Or are the delicate nutational movements of the growing-point also significant in this connection? Every now and then, in abnormal forms of growth, it is as though the "spiritual staff" were to lose its silent power; growth is caught up as if into a vortex. Such for example is the valerian plant, of which a picture is included in some editions of Goethe's work.

Chapter II
Gesture of the Growing Plant

10. Leaves at the Growing-Point. It is a wonderful paradox of Nature that the upward-shooting plant brings forth materials and forms which both in use and in appearance are proverbial for their radial penetrating power, yet there is little of this quality in the way they first come into being. The upright stem does not *thrust* its way into space like an arrow or a spearhead. The upward-growing power of the shoot is indeed one of the mightiest phenomena we know, and the eventual outcome of it is a thing of strength in the realm of earthly pressures and tensions—formed into pillar and pile, spoke and ramrod for human use from ages past. Yet it was not with this earthly-radial quality that the growing shoot made its way up and outward.

Not only are the growing tissues delicate and watery; the same is true of nearly all living, growing things, including the downward-tending root which has indeed a radial quality of form and growth. It is not merely the delicate material; it is the form, the gesture of the growing shoot to which we specially refer. Describing it exactly as we see it, the typical phenomenon at the growing-point is the very opposite of a spearhead. What we behold at the tip of the growing shoot is concave and not convex; it is a hollow space we nearly always see. The actual growing-point of the stem is deeply hidden amid the young enfolding leaves. Their gesture is as if to guard, there in the empty space between them, a hidden treasure with protecting hands. The youngest leaves reach upward, sometimes in pairs and very close together, sometimes in whorls forming a hollow cone, first deep and steep, thence gradually opening and flattening. Often each single leaf is concave on its inner side, making the hollow space more spherical and cup-like.

Leaf after leaf, whorl after whorl with further growth expands and comes away, opening more or less towards the horizontal; meanwhile within them, other, younger buds have grown to take their place. So long as the shoot is growing, the gently guarded hollow space is there. It is a characteristic gesture that delights us, in all varieties of eloquence and beauty, all through the spring and early summer. Passing the height of summer. when we see less and less of the upward and enfolding gesture of young leaves but nearly all have opened full and flat, we know that this year's outward growth is ending.

This concave quality of upward growth is an essential feature of the impression we receive from the green plants that bedeck the Earth around us. The plants live by the light, coming to Earth from the Sun, from cosmic spaces. Pictorially, it is as though each single shoot were reaching out to receive and hold its portion of the light. All this contributes to the peculiar feeling of freshness and buoyancy the plant-world gives us. Leaf and leaf-bearing branch, as they grow older, do indeed tend out towards a planar and even horizontally flattened form; yet for the most part they retain something of the up- and inward gesture. Where the leaf does not flatten to the likeness of a plane, it is indeed not always but in the majority of cases concave on its upper ventral surface.

How characteristic this impression is, we may also tell from what we feel when it is absent, or when the ageing portions of a plant have lost it. If the plant lacks the hollow gesture altogether—like many cactus-forms for instance—it looks ungainly, quaint and untypical amid the higher plants.

11. Leaf and Plane. With the unfolding of leaf and branch is associated another quality which we perceive and feel in the phenomenon of plant-life above the soil, though Science hitherto has lacked the corresponding concept. The leaves, as we said, tend to unfold towards a plane. They are, in a sense, *planar organs.* It is not only the crude quantitative fact that they develop a far greater surface-area than

thickness; in their whole quality, function and morphological gesture they reveal that the character of "plane" belongs to them, just as the character of "point" belongs to every earthly object by virtue of its mass and weight,—namely its centre of gravity.

We know the quality of "plane" first and foremost in the horizontal surface of the Earth around us. (Ideally, it is the tangent plane to the Earth's sphere at the particular point where we are.) We experience it if ever we look out over a wide open plain or over the still surface of a lake. And now in countless instances the fully opened leaves of plants—often the branches too, which bear them—make manifest this horizontal plane, or rather many parallel planes, one above the other. We see it when the sunlight falls through the young leaves in the beechwoods in May and June. A myriad planes seem to hover in the sunlit air. The impression we thus receive from the outspreading leaves is one of buoyancy and lightness. They seem to be upborne. This sense of buoyancy contributes to the feeling of life and refreshment which makes us glad to bring not only flowers but green leaves and twigs into our dwellings.

When we are looking through clear water at aquatic plants, we see the shoots buoyed up by the surrounding element and can interpret the phenomenon by the well-known law of hydrostatics. Yet for our vision and spatial feeling there is undeniably a like quality of buoyancy—even a stronger, more active one—about the upward striving and outspreading gesture of the terrestrial plants, though there is here no dense material element which in the Archimedean sense would relieve them of their weight. These are again the pure phenomena for which we shall be seeking the ideal counterpart, the interpretation.

12. The Flower's Chalice. At the tip of a vegetative shoot the nodes and internodes are crowded together; often the leaves of many nodes combine to enfold the hollow space above the growing-point. Internodes lengthen out quickly as the plant shoots upward, but at the tip a younger sequence of unfolding leaves maintains the form.

When in its further metamorphosis the plant comes to flower, the gesture of a hollow and enfolded space is all the more enhanced. The changing of foliage- into flower-leaves goes hand in hand with a relative cessation of upward growth; many potential internodes are whorled together and cease to lengthen out. This is the next Goethean phase of "contraction and expansion." The flower-bud enwraps a space more tightly closed, and when we see it open to a flower it is as though the space were now poised in silence. What the growing tip of the vegetative shoot suggested in an ever-changing form—in an enfolded space, ever unfolded and renewed again from within—this is now brought to rest in the flower-chalice, maintained as long as the blossom lasts. And in this "chalice," something hitherto unmanifest about the plant is now revealed, both in the form and pattern of the flower, by which the classifying botanist mostly discerns the individuality and type of plant, and above all in colour, texture, fragrance. One is inclined to say: if the hollow space tended by the young unfolding leaves, going before the apex of the stem as it grew upward, was not just emptiness but had a deeper meaning, its presence indicating a real sphere of forces scientifically still to be defined, then in the flower something more of this ideal space has been made visible. What hitherto induced the upward and unfolding growth, yet in its quality remaining latent, has now revealed its essence in another way. The material, sense-perceptible part of the plant has united with it more deeply than hitherto.

The flower, too, often unfolds its petals to a plane or even turns them back. Again, the hollow may be deeply exaggerated to a bell or tube, or sundry forms of nectary and spur. Yet in the main the cup-like form—in every degree of openness—is the most frequent and to imagination the most typical. If we have watched the enfolding and unfolding gesture of the green leaf-bearing shoot, our feeling of the flower-form's significance is all the more enhanced.

13. The Fruit: Goethe's third " Expansion." In our description we have now followed two of the three Goethean cycles of expansion. *One*: the unfolding of successive leaves and leaf-bearing side-shoots from the hollow space above the stem-tip—tiny at first, already adumbrated in the relation of cotyledon and plumule, and then expanding, undergoing variation, yet in essential quality remaining constant. *Two*: the unfolding of the flower, in quality quite different and preceded by a potent phase of contraction in the flower-bud and calyx. When at long last the flower-bud unfolds, the new expansion in its purely spatial, quantitative aspect is as a rule less lavish and less free; it is an opening rather of glory, a shewing-forth of the plant's individual essence and essential beauty. Such is the second expansion —no mere variation but a true " metamorphosis,"—in quality quite different from the first.

When we now come to Goethe's third and last expansion—the swelling of the fruit—we find an even greater change. Now for the first time the higher plant, in the shoot, attains a predominantly *convex* form of growth. It is as though the hollow sphere, hitherto so immaterial, its presence only indicated by the enfolding leaves or by the cup-like gesture of the flower, were now for the first time to be filled with substance. For at this third expansion it is no empty, airy space that opens out, nor does the plant extend its body merely one- or two-dimensionally as in the slender forms of stem and leaf, but now the sap and growing tissues fill the whole volume of the fruit. We have the typical sphere-form of the apple or its equivalent in many variations. Heavily laden, the shoots that hitherto reached upward, bearing the hollow space at the growing-point or the fragile flower, are now weighed down with their fruity burden. Or the fruits harden into capsules, typical three-dimensional forms reminiscent rather of the mineral kingdom, or like strong ornamental caskets made by human hand.

This is again the enriching paradox of the life of plants through the summer season. From delicate and unsubstantial forms, now with amazing quickness is produced the earthly store of fruit and grain, to be weighed and garnered.

14. " Convex and Concave " in the Forms of Growth. The full significance of these familiar facts will dawn upon us if we compare the higher plants with other forms of life, both in the vegetable and in the animal kingdom. Life has its origin and home in the watery element and manifests itself in growth. The primary and simplest form is a sphere, living in a watery medium, filled with watery or semi-fluid living substance and differentiated from its surroundings by some form of skin or surface-layer. The living sphere grows, drinking in water and other substances at the expense of its surroundings. This is the primary phenomenon of convex, outward growth. We find it in the microscopic, cellular organization of all living and growing things, including of course the higher plant—root, shoot and leaf without exception. But the cellular growth is here subservient to macroscopic forms of life, visible to the naked eye and more significantly diverse.

Every material body must ipso facto be predominantly convex towards the surrounding world, for it must be contained within a finite radius and volume. A living body therefore takes its start from the simplest of convex forms—the more or less spherical shape of the seed or germ-cell—and in its outline as a whole, whatever hollowings and folds, ramifications, incisions and excrescences it may involve, it must have something of the self-containedness of a finite convex form. So has the tree for example, which when we see it in winter-time shews very beautifully its convex outline, though this is formed by myriads of twigs and branches through which we see the sky. In effect, convex though it must be in this sense, being a thing in the material world, the higher living organism reveals the interplay of an opposite, a concave principle of form. Yet the way in which it does so is profoundly different in the plant and in the animal kingdom.

In the animal, it is the well-known principle of gastrulation—*invagination.* Thus in the lower animals where the simplest archetype of this process is revealed, the primary, spherical form of growth, the blastula, is hollowed from one end and folded in upon itself. In the resulting gastrula the original interior of the sphere—known as the segmentation-cavity or "blastocoele"—has now become the space confined and often more or less obliterated between the outer and inner folds, while a new hollow space, the "enteron," is formed within the latter. This kind of "invagination"—the turning-outside-in, the hollowing of originally convex forms—is repeated again and again in the course of animal development and embryology. To a great extent the complex and yet closely knit animal body, with its internal organs, its convolutions and membranes folded back upon themselves, is by such means produced.

The plant appears the very opposite of this. Its essence is to grow ever outward. Yet here too, in the shoot, a concave principle of growth reveals itself, as we have seen. But this concavity tends in the opposite direction. It is not like the dark and inward process of invagination. Out in the light and air, even by the upward and outward growth of the young leaves, a hollow space is formed at the tip of the growing shoot; deeply and closely enfolded as it so often is, yet it is only formed to be progressively *un*folded. In fact the plant-shoot lives and grows—if we may coin this expression—by a perpetual process rather of *e-vagination.* Such is its characteristic.

The higher plant does not shoot forth with a mere earthly-thriving life, sending forth spherical or elongated organs that would seem merely to thrust their way outward into space. (Such indeed is the form of growth of many of the lower plants—the fungi and to some extent the algae.) It reaches outward to a hollow space, which it then gives away as it unfolds. We only fail to recognize this because the hollow space seems empty; as it were, there *is* nothing to unfold from. When the animal infolds its gastrula—forming its *Urdarm* as Haeckel called it, its archetypal stomach or intestine—we know at once what this signifies, for into such an organ food, for example, will be ingested. But when the plant—which, as we know, *gives* more than it takes in the economy of life—pours out as it were the hollow space which it at first enfolded with such tender care, nothing is there to see but the surrounding light-filled air, and it requires an awakened insight to relate this very characteristic morphological gesture to the prime function of the green plants, which is to bestow life-giving oxygen and also nutritive substance both on themselves and on all other earthly creatures.

15. Unfolding Growth and Plastic Outline. The synthesis of concave and convex, upward- and downward-opening forms belongs to the peculiar magic of the higher plant, both herb and tree. The characteristic outline of a pine-tree* is of a cone widening downward from the apex, more or less dark and opaque against the sky. Yet in the process and form of growth by which it comes into being we see the opposite: a hollow cone that opens upward,—a gesture that begins already with the seedling and is repeated again and again in leaf and branch. This is a simple emblem of a more universal phenomenon. The opening from a deep hollow sphere or cone—characteristic of the youngest leaves and branches—expanding and flattening from thence towards the horizontal, while simultaneously the apex of the stem and the plant's outline as a whole springs forth and outward to form a sphere- or cone-form, convex and as a rule widening downward from the apex: such is the growth of the plant in process and in outcome.

In the herbaceous plants with their more open growth the "outline as a whole" is often less in evidence, but the same principle will appear in the inflorescence, the development of which, as Goethe shews, involves an element of condensation,—of contraction. We see the manifold, more or less closely packed inflorescences, conical as in the lupin, or spherical as in clover or hydrangea, or even more closely knit as in the composite family. Each single flower still has the cup- or tube-like form, only the inflorescence

as a whole is convex. Yet the latter too was in its early stages deeply hidden—a mass of buds down in the hollow of protecting leaves. Thence it emerged, shooting up- and outward.

We may apply to this aspect of the growth of plants the ancient symbol of the two interlacing triangles —Solomon's seal,—only we must change it from a dead static form into a functional, dynamic image. Multiply the upward-open triangle—we have the gesture of the growing leaves and branches. The single downward triangle typifies the form of the plant as a whole. As a two-dimensional image, this is already the type of many leaves with their triangular shape and spreading veins. Rotated about the vertical axis, we have the twofold cone-form, as in the pine.

16. The Higher Plant's Fulfilment. Let us now look once more at the three stages. In the higher as against the lower plant, it is as though there were a focus of life and growth which is not immediately claimed by the material, watery-earthly body. The plant tends upward to this focus, enveloping it with its green leaves, which unfold and come away from it in turn. The flower then envelopes it more closely, no longer growing outward and away but pausing, and at the same time seeming to come into a nearer relation with whatsoever has been hidden here,—making it manifest in colour, form and beauty. Yet still the hollow space remains; the inner focus has not yet been claimed. Only when the flowering process and with it the "fertilization" is complete, does the fertilized ovary grow right up into the living focus, or draw the virtue of it down into its substance. Now comes the third expansion; this at long last is material, three-dimensional, filled from within,—growth at this stage is convex.

The plant has waited till this third stage to claim for its material life and body what it has hitherto left free and open. And when we contemplate the whole sequence of these phenomena, we see that to this waiting, this refraining, it owes its light and its airy beauty. When at long last it comes to fruit and seed, uniting its earthly substance with the ideal sphere which until now it left untouched, the outcome is a greater fragrance and individual variety of substance than is afforded by the lower and more rapidly fulfilled forms of life.

17. Root and Shoot. All that we commonly see of the plants around us are the leaf- and flower-bearing shoots; the roots are mostly hidden,—do not become "phenomenon" until we dig them up. This too is significant, and it is not without meaning that Goethe the great phenomenalist, who derived so much of his perception from the sense of sight, says little of the root. The individual essence of the plant is manifested far more in the shoot; down in the dark community of Mother Earth there is not only the "mycorrhizal" but there are many other "associations;" this is far more of a *common* sphere of life. So too the botanist learns from the character of roots in general, but the roots tell him far less—comparatively speaking—about the individual character of one plant or another. We base our classification first and foremost on the flower, to a lesser extent on the leaf-bearing shoot, and least of all on the root.

Yet we must contemplate the plant as a whole—root and shoot—even to shed a fuller light upon the form and gesture of the shoot itself. At the ground-level—the region commonly known as the "hypocotyl," where the root passes over into the shoot—the plant is drawn together; here the cross-section is comparatively small. Thence it expands—downward and upward, but in very different ways. Upward as we have seen, the plant achieves its expanded space by a concave, enveloping, embracing form of growth. Even the ultimately radial and convex forms—most prominent in the tree, which becomes most earthly—come into being by means of this other mode of growth, the form and gesture of which predominates in many a herbaceous plant throughout its life.

Downward on the other hand into the root, the growth is truly radial from the beginning, and this is fitting, since the root enters far more deeply into the earthly realm. The primary earthy-mechanical forces

are radial—that is to say, working along a line from one point to another,—wherefore our engineering structures so often take the form of a network of girders, "struts and ties." Taproot reaching vertically downward, or wide and ramifying system, the very form of the root suggests its adaptation to a realm in which the material and earthly forces are most at home.

We find a corresponding difference between stem and root in internal structure. Thus at the hypocotyl there is a peculiar interchange of what is inner and outer. The concave and enveloping tendency of the shoot also finds expression in the *cylindrical* character of the stem, which, if not actually hollow, mostly develops its essential organs, vascular bundles and cambium, in a cylinder around the pith or woody trunk. It is from this outer enveloping portion of the stem that the side-shoots spring. In the primary root on the other hand the vascular system is internal, forming a central core, and the lateral roots spring from this inner region, forcing their way through the outer layers.

18. Radial below, Enveloping above. Sometimes a human craftsman makes a wineglass form of cup or chalice rather like an emblem of this twofold nature of the plant—perhaps suggested by it. The slender stem must be supported on a wider base, and if this is chased and moulded on a more radial pattern as it often is, we have the dual form in question—radial below, enveloping above.

But the plant-shoot is a plastic, ever-changing growth—at least until it comes to flower. It forms the gesture of a chalice, as we have seen, only to open it out, forming another cup within the first. So it repeats the process, rhythmically, node by node. Moreover it can only do this inasmuch as the older nodes are progressively thickened and strengthened, so as to bear the younger and more delicate portion of the shoot ever upward. The lower portions of the stem partly take on the supporting function of the root; they act as mediators between the actual root and the younger more living organs. To some extent there pertains to every node a modicum of the same function which belongs to the hypocotyl. How easily, in many plants, the node reveals this potentiality; transplanted under the right conditions, it will develop root as well as shoot.

Thus is the dual relationship rhythmicized and repeated. Botanists have compared the "morphological polarity" of the plant to the polarity of a magnet; the analogy is of course unsatisfying, for there is not enough qualitative difference between the north- and south-seeking poles. In the next chapter we shall see how a far more qualitative, morphologically true polarity may be discerned. For the moment however accepting the rough-and-ready picture, we may recall how a bar-magnet can be broken ever so many times along its length; each fragment will reveal the same polarity as the original whole. Moreover, given the opportunity, they will attract each other, end to end, tending to restore the whole both in form and function. Potentially it is as though the single magnet were already divided into ever so many partial magnets, all along its length. Something like this is the plant, but in a far more living way,—with the caesuras marked not by arbitrary breaking, rather by rhythmic integration.

19. Cup within Cup. It follows therefore that the upward-opening and concave gesture by which a lower portion, rooted in the ground, carries the upper like a cup or chalice, pertains not only to the plant as a whole but is at least potentially repeated from node to node, cup within cup. Often however this relationship would only become visible if, so to speak, in the mind's eye we could add a time-dimension—if we could quickly and imaginatively follow the life of the plant backward in time and see the opened leaves at the lower nodes returning to their erstwhile gesture.

If this be a true reading, we shall expect to find that in some plants at least it becomes phenomenon. Indeed the cup-within-cup, hollow-within-hollow quality is very often in evidence. On a rather primitive level it appears in the peculiar segmentation of the equisetum-shoot, each segment springing from

within the serrated leaf-sheath of the last. We see it in the habit of the grasses, where the lower portion of each leaf forms a sheath about the stem—or about the sheaths of younger leaves—reaching far up to where the ligule is. We see it too in the frequent tendency of the base of the petiole or leaf-stalk to envelop the parent stem, so that each internode of the latter grows out of an embracing hollow. Most eloquent, where a pair of opposite leaves arises at each node, are the connate forms such as we find in certain leaves of honeysuckle, or as a deep vessel in the teasel.

It is an archetypal form—this tendency of each successive shoot or internode to spring from within a hollow sphere, borne by the last. Only the extent to which it is revealed, varies from plant to plant; sometimes there is little outward sign.

Very significant in this connection are the plants—like daisy, dandelion, even plantain—where a tall flower-bearing stem springs from a rosette of leaves at the hypocotyl. Though older leaves may be lying flat against the ground, such a rosette, taken as a whole, nearly always has a concave and embracing gesture, as if towards an ideal sphere into the focus of which the flower grows. What this simple type of plant shews as it springs from the earth, others transform into a rhythmic and repeated process. The normal flower brings it to a close; the flower-cup is final. Goethe learned much from those abnormal cases of proliferation where even here a further shoot springs forth.