JOHANN WOLFGANG v. GOETHE

THE METAMORPHOSIS OF PLANTS

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With an Introduction
by Rudolf Steiner

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Contents

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ORIGIN OF THE THEORY OF METAMORPHOSIS

RUDOLF STEINER

I

On August 18, 1787, Goethe wrote from Italy to Knebel: "After what I have seen of plants and fishes in the region of Naples, in Sicily, I should be sorely tempted, if I were ten years younger, to make a journey to India—not for the purpose of discovering something new, but in order to view in my way what has been discovered."

In these words is to be found the point of view from which we have to consider Goethe's scientific work. What he was concerned with was never the discovery of new facts, but the laying open of a new point of view, a particular way of looking upon nature. It is true that Goethe made a number of great individual discoveries, such as that of the intermaxillary bone and the vertebral theory of the skull in osteology, the identification of plant organs with the leaf in botany, and the like. But we have to view as the animating soul of all these particularities a lofty view of nature upon which they rested; in the history of organisms, we have to fix our attention primarily upon a notable discovery which reduces everything else to insignificance: that of the nature of the organism itself. The principle by reason of which an organism is that which it represents itself to be, the causes which result in the phenomena of life appearing before us—indeed, everything that we have to inquire about in this regard from the point of view of principles—have been laid bare by him. From the very beginning, this was the objective of his whole endeavor in the organic sciences; while he was pursuing this objective, these particularities crowded upon him as if of themselves. He had to discover them if he wished not to be hindered in the further prosecution of his efforts.

The natural science which preceded him—which did not recognize the essential nature of life phenomena, and which investigated organisms simply with regard to the manner in which they were composed of parts, their external characteristics—often inevitably gave a false interpretation of details which it came upon on this path, often set these facts in a false light. Naturally, it is impossible to discover such an error in connection with the details. We recognize this only when we understand the organism, since the details, considered separately in themselves, do not bear within them their own interpretive principle. They are to be interpreted only through the nature of the whole, since it is the whole which gives them real being and significance. Only after Goethe had discovered, indeed, this nature of the totality did those erroneous explanations become clear to him; they could not be reconciled with his theory of the living entity, but contradicted this. If he wished to proceed further on his course, he had to get rid of such preconceptions. This was the case with the intermaxillary bone. Facts which have value and interest only when one possesses those theories, such as the vertebral character of the skull bones, were unknown to that older natural science. All these hindrances had to be removed through single discoveries. These, therefore, never appear in the case of Goethe as goals in themselves; they always have to be made in order to confirm a great idea, that *central discovery.*

It cannot be denied that Goethe's contemporaries came, sooner or later, to the same observations, and that all would be known today, perhaps, apart from the endeavors of Goethe. But it is still less to be denied that his great discovery, embracing the whole of nature, has never been affirmed until the present time by any second person in equally admirable manner independently of Goethe—indeed, even a reasonably satisfactory evaluation of this discovery is still lacking. Fundamentally considered, it is clearly a matter of indifference whether Goethe was the first to discover a fact, or only rediscovered it. The fact gained true significance only through the way in which he fits it into his view of nature. It is this that has hitherto been overlooked. The separate facts have been too much emphasized, and this has given rise to polemics. It is true that Goethe's settled belief in the consistency of nature has often been referred to; only, the fact has been overlooked that this provides us with only an entirely subordinate characteristic of Goethe's views, not of great significance, and that the matter of primary importance in connection with organic science, for example, is to show what is the character of that which maintains this consistency. If one calls this the *Type*, it is necessary to say wherein the nature of the Type consists according to Goethe's conception.

What is significant in the theory of the metamorphosis of plants, for example, does not lie in the discovery of the single fact that leaf, calyx, corona, etc., are identical organs, but in the magnificent thought-structure of a totality of mutually interpenetrating formative forces which proceeds from this discovery and determines out of itself the details, the single stages in the evolution. The loftiness of this idea, which Goethe then sought to extend to the animal kingdom, becomes clear only when one seeks to bring it to life in one's own mind, when one undertakes to rethink it. We then become aware that this thought is the very nature of the plant itself, translated into the idea and living in our own mind just as it lives in the object. One observes also that an organism thus comes to life within one, even down to its most minute parts: that one conceives it, not as a lifeless, self-enclosed object, but as something evolving, becoming, as the continuously unresting within itself.

As we endeavor in what follows to set forth in detail all that has been hinted at, the relationship will become clear between Goethe's view of nature and that of our own age—especially the theory of evolution in its modern form.

II

In tracing historically the origin of Goethe's thought regarding the morphology of organisms, one may all too easily fall into doubt as to the part that is to be ascribed to the period of the poet's youth—that is, the time before he went to Weimar. Goethe himself attached little value to his scientific knowledge during that period. He said: “Of what really constitutes external nature I had no conception, and of her so-called three kingdoms not the least knowledge.” On the basis of this assertion, it is generally thought that the beginning of his scientific reflections occurred after he came to Weimar. Yet it seems advisable to go further back, if one is not to leave unexplained the whole spirit of his conceptions. The animating impulse which guided his studies in the direction we shall later explain is apparent even in his earliest youth.

When Goethe entered the University of Leipzig, the spirit still completely dominant there in all scientific endeavors was that which characterized a great part of the eighteenth century, which separated the totality of knowledge into two extremes that no one felt the need to unite. On one side was the philosophy of Christian Wolf (1679-1754), which moved wholly in an abstract realm; on the other side, the individual branches of the sciences, which were lost in the external describing of endless details, and wholly devoid of any effort to discover a higher principle in the realm to which the objects of their research belonged. That philosophy could not find its way out of the sphere of general concepts into the realm of immediate reality, of the individual existence. In it the most self-evident things were treated with utmost detailed thoroughness. One learned that the *Thing* is something which has no contradiction in itself; that there are finite and infinite substances; and so on. But if one brought these generalities to bear upon things themselves in order to understand their mode of action and their life, one was left quite helpless; it was impossible to apply these concepts to the world in which we live and which we wish to understand. The things around us, however, were described in a manner largely void of any principle, purely according to their appearance, their external characteristics. On the one hand, there was a system of knowledge dealing with principles which lacked a living substance, a loving absorption in the immediate reality; and, on the other, a system of knowledge void of principles, which lacked the substance of ideas. They confronted each other without any mediation, each fruitless for the other. Goethe's wholesome nature was repelled in equal manner by each of these one-sidednesses; and, in his opposition to them, there developed in him conceptions which later guided him to that fruitful view of nature in which idea and experience in complete reciprocal interpenetration mutually animate each other and combine to form a whole.

The concept, therefore, which exponents of those extremes could least of all grasp developed for Goethe as the very first: *the concept of life.* When we reflectively observe a living creature in its external manifestation, it exhibits a great number of details which appear as its members or organs. The description of these members, as to their shapes, relative positions, sizes, etc., might constitute the content of an extensive treatise, to which the second of the two schools of thought we have described devoted itself. But the mechanical construction of any inorganic body could also be described in the same way. It was altogether forgotten that, in the case of the organism, one must keep clearly in mind most of all the fact that here the external manifestation is determined by an inner principle; that in every organ the totality is active. That external phenomenon, the spatial juxtaposition of the members, can be observed also after the destruction of the life; it continues still for a certain time. But what confronts us in a dead organism is, in reality, no longer an organism. That principle has disappeared which permeated all the individual parts. *Against that way of observing which destroys life in order to know life, Goethe opposed very early the possibility and the necessity for a higher way of observing.* We see this even in a letter of the Strassburg time, of July 14, 1770, in which he says of a butterfly: “The poor creature trembles in the net, rubs off its most beautiful colors; and, if one catches it intact, yet it sticks there at last stark and lifeless; the corpse is not the whole creature; something else belongs to it—another principal part, and in this instance as in all others a primary principal part: the *life*. . .” The same view gives rise also to the following lines in *Faust*:

Who wishes the living to know and describe
Seeks first the spirit thence to drive;
Then all the parts he has in his hand—
Lacks only, alas! the spiritual band.

With this denial of a certain view Goethe did not content himself, but—as was to be assumed from his nature—he sought more and more to develop his own view; and we recognize very often in the indications available to us of his thinking from 1769 to 1775 the germinal ideas for his later works. He was developing the idea of an entity in which every part animates every other, in which one principle permeates all the details. We read in *Faust*:

How all a single whole doth weave,
One in the other works and lives.

And we read in *Satyros*:

In Nothingness that Primordial gushed;
Light's mighty voice through the darkness rushed,
To every being's depth brought fire,
Waking to life the germs of desire;
The elements opened to one another,
Hungering each of them for the other,
All-permeating, all-permeated.

This entity is conceived as being subject to continuous changes in time, but in all the stages of these changes only one being is constantly manifest, asserting itself as that which endures, that which is stable amid change. We read further in *Satyros* in regard to this primordial thing (*Urding*):

And up and down did rolling swing
The all and one eternal Thing,
Changing ever, the same forever.

One should compare with this what Goethe wrote in 1807 as the introduction to his theory of metamorphosis: “If, however, we observe all forms, especially the organic forms, we find nowhere something continuing, nowhere something at rest, concluded, but, on the contrary, that all is in continuous fluctuating movement.” With this fluctuating element he contrasts there the Idea—or “something held fast in experience only for the moment”—as that which is constant. It will be recognized clearly enough from the passage quoted above from *Satyros* that the foundation for Goethe's morphological ideas had already been laid before he came to Weimar.

But what must be held firmly in mind is that this idea of a living entity is not applied at once to an individual organism, but that the entire universe is conceived as such a living being. The initial incitement in this case is certainly to be found in the alchemistic work with Fraulein von Klettenberg and in the reading of Theophrastus Paraceleus after Goethe's return from Leipzig (1768-69.) The endeavor was made through some sort of experiment to lay hold upon the Principle permeating the entire universe, to exhibit it in a substance. Yet, this way of reflecting about the world, bordering upon the mystical, constituted only a transitory episode in Goethe's development and yielded very soon to a more wholesome and objective manner of thinking. The view of the entire universe as a great organism, as we find this indicated in the passages cited from *Faust* and *Satyros*, was still maintained, however, approximately until 1780, as we shall later see from the essay on *Nature*. It appears still once more in *Faust*, in the passage where the Spirit of the Earth is represented as that Life Principle interpenetrating the All-Organism:

In tides of life, in storms of action,
Up and down I wave,
Weave I hither and yon,
Birth and the grave,
A sea without bound,
A changeful weaving,
A radiant living.

While definite views were thus developing in Goethe's mind, there came into his hand in Strassburg a book which sought to establish a world view precisely opposite to his own. This was Holbach's *Systeme de la nature*. If he had until then to complain only that the living entity was described like a mechanical heap of individual things, he became acquainted in Holbach with a philosopher who actually looked upon the living creature as a mechanism. What was due in the other cases only to a lack of capacity for recognizing life down to its roots led in this instance to a dogma which inflicted death upon life. In *Dichtung und Wahrheit*[*], Book II, Goethe says in regard to this: “Matter was assumed to have existed from eternity, to have been in motion from eternity, and to have brought forth with this motion, right and left in all directions, the endless phenomena of existence. With all this, we should have been contented if the author had actually built the world up before our eyes out of this matter in motion, but he was able to know just as little about nature as we; and, while he hammered in some generalizations, he abandoned these immediately in order to transform that which is higher than nature, or which appears as a higher nature within nature, into a heavy, material nature—in motion, indeed, yet without direction or form—and believed that he had thus achieved a good deal.” In all of this Goethe could find nothing except “matter in motion,” and in opposition to this his own concepts of nature took ever clearer form. We find these brought together and presented in the essay *Nature*, which was written about 1780. Since all of Goethe's ideas about nature which we have thus far found only scatteringly indicated are gathered together in this essay, it gains a special significance. The idea here confronts us of a Being which is in a state of constant change and yet ever remains the same: “All is new and always the old.” “She [nature] is forever changing and in her there is nothing standing still a single moment,” but “her laws are unchangeable.” We shall see later that Goethe sought in the endless multitude of plant forms for the one archetypal plant (*Urpflanze*). Even this idea we find here already indicated: “Each of her [nature's] works has an essential nature of its own, each of her manifestations a most isolated concept; and yet all comprises only one.” Indeed, the position which he later took in reference to exceptional cases—that is, not to consider them simply as defective formations, but to explain them on the basis of natural laws—is here quite clearly affirmed: “Even the most unnatural is nature,” and “her exceptions are rare.”

We have seen that, even before Goethe went to Weimar, he had already developed a definite concept of an organism. For, even though the essay *Nature* belongs to a much later period, it contains for the most part earlier views of Goethe. He had not yet applied this concept to a definite genus of natural objects, to individual creatures. For this purpose he required the concrete world of living entities in immediate actuality. The reflection of nature which had passed through the human mind was never the element which could stimulate Goethe. The conversations on botany in the company of Hofrat Ludwig in Leipzig were without any deeper influence than the table conversations with medical friends in Strassburg. As regards scientific studies, the young Goethe appears to us like Faust deprived of the freshness of the direct beholding of nature, as Faust expresses his longing for this in the words:

Oh, could I to the mountain height
Ascend in thy most blissful light,
With spirits hover by mountain caves,
On meadows wander thy twilight laves.

It seems like a fulfillment of this longing when, upon his arrival in Weimar, he was permitted "to exchange the air of a room in the city for the atmosphere of the country, the forest, and the garden."

We must consider as a direct incentive to the study of plants the poet's engrossment with the planting of the garden given to him by the Archduke Karl August. The acceptance of the garden by Goethe took place on April 21, 1776, and his diary, edited by Keil, informs us frequently from this time on about his work in this garden, one of his favorite occupations. An added area of activity in this direction was afforded him by the Thuringian forest, where he had the opportunity to acquaint himself also with the life phenomena of the lower organisms. He was especially interested in the mosses and lichens. On October 31, 1777, he requested of Frau von Stein mosses of all sorts, damp and with roots whenever possible in order that they might be propagated. It must needs appear to us highly significant that Goethe was occupying himself here already with these organisms of a very low order, and yet traced the laws of plant organization later from the higher plants. This circumstance should not be attributed, as is done by many, to an underestimating of the significance of the less highly evolved entities but to a clearly conscious purpose.

From this time on the poet never abandons the world of the plants. He was probably occupied very early with Linne's[*] writings. We learn first of his acquaintance with these from letters to Frau von Stein of the year 1782.

Linne's efforts tended in the direction of bringing into the knowledge of plants a systematic lucidity. A certain system was to be discovered in which each organism would occupy its specific place, so that it could easily be located at any time—indeed, that there might be a means of orientation in the endless multiplicity of single entities. To this end, the living entities would have to be studied with respect to the degrees of their kinship, and put together into groups corresponding to these grades of kinship. Since the most important thing of all in this undertaking was to know every plant and to find readily its place in the system, it was necessary to pay special attention to those characteristics which differentiate the plants from one another. In order to render impossible the confusion of one plant with another, special search was made for these differentiating marks. In this regard, Linne and his students considered as characteristic such external differences as size, number, and position of individual organs. In this way the plants were, indeed, arranged in a series, but just as a number of inorganic objects could have been arranged—according to differentiations which were based upon the external appearances, not the inner nature, of the plants. They appeared in an external juxtapositon, without inner necessary connection. Because of the significant concept which Goethe held of a living entity, this manner of reflection could not satisfy him. There was no endeavor at all here to discover the true nature of the plant. Goethe had to set before himself the question: Wherein consists the "something" which makes a particular entity in nature a plant? Moreover, he had to recognize that this something appears in like manner in all plants. And yet there were the endless differences among the individual entities, which demanded explanation. How is it that this *One* reveals itself in such manifold forms? These may well have been the questions which Goethe raised as he read the writings of Linne, for he says of himself: "That which he [Linne] sought by force to hold apart had, according to the innermost urge of my nature, to strive toward union."

At about the same time as the acquaintance with Linne came also that with the botanical efforts of Rousseau. On June 16, 1782, Goethe wrote to Karl August: "In Rousseau's works there are the most charming letters about botany, in which he expounds this science to a lady in the most intelligible and elegant manner. It is truly a model of how one should give instruction, and forms a supplement to *Emile*. I take occasion, therefore, to recommend anew to my beautiful lady friends the beautiful kingdom of the flowers." Rousseau's efforts in the field of botany must have made a deep impression on Goethe. The emphasis that we meet in Rousseau upon a nomenclature arising out of the nature of the plants themselves, the originality of observations, attention to the plants for their own sake, apart from any utilitarian principle—all of this was wholly in keeping with

Goethe's attitude of mind. They shared also in the fact that they had come to the study of plants, not through the development of a special scientific endeavor, but from a general human motive. The same interest bound them to the same object.

The next thorough-going observations of the plant kingdom occurred in the year 1784. Wilhelm Freiherr von Gleichen, called Russwurm, had at that time published two writings dealing with subjects of research which interested Goethe intensely—*Das Neueste aus dem Reiche der Pflanzen*[*] (Nuremberg, 1764) and *Auserlesene mikroskopische Entdeckungen bei den Pflanzen*[†] (Nuremberg, 1777-81). Both writings dealt with the fertilization processes in plants. The pollen, stamens, and pistils were thoroughly studied, and the processes connected with them were represented in beautifully produced plates. Goethe now repeated these researches. On January 12, 1785, he wrote to Frau von Stein: “My microscope has been set up for the purpose of repeating and verifying with the arrival of spring the researches of Gleichen, called Russwurm.” During the same spring the nature of the seed was also studied, as we see from a letter of April 2, 1785, to Knebel: “The subject of the seed I have thought through so far as my experience renders possible.” In all these researches, what Goethe was concerned with was not the detail; the goal of his efforts was to investigate the true nature of the plant. He reported in regard to this to Merck on April 8, 1785, that he had made “nice discoveries and combinations.” The expression *combinations* here also shows that what he was aiming at was to outline in thought a picture of the processes in the plant kingdom. The study of botany rapidly approached a definite goal.

Of course, we must bear in mind in this connection that Goethe had discovered in 1784 the intermaxillary bone, which we shall later discuss in detail, and had thereby made significant progress toward the mystery of nature's procedure in the forming of organic entities. Moreover, we must recall that the fist part of Herder's *Ideen zur Philosophie der Geschichte der Menschheit*[*] was completed in 1784 and that Goethe and Herder conversed frequently at that time on subjects pertaining to nature. Thus Frau von Stein reported to Knebel on May 1, 1784: “Herder's new writing makes it seem likely that we were first plants and animals . . . Goethe ponders now with abundant ideas about these things and what has first passed through his mind becomes extremely interesting.” We see from this the character of Goethe's interest at that time in the greatest scientific questions. Thus his reflections about the nature of plants and the combinations he made among them in the spring of 1785 must appear quite natural.

In the middle of April of this year he went to Belvedere for the express purpose of reaching conclusions as to his uncertainties and questions, and on May 15, he sent the following message to Frau von Stein: “I cannot tell you how legible the book of nature is becoming for me. My long continued deciphering, letter by letter, has helped, and now all of a sudden it works, and my quiet joy is inexpressible.” A short time before this he even wished to write a brief botanical treatise for Knebel in order to win him for this science. Botany attracted him so strongly that a trip to Karlsbad, which he began on June 20, 1785, in order to spend the summer there, became a botanical excursion. Knebel accompanied him. In the neighborhood of Jena they met a seventeen-year-old youth, Dietrich, whose botanizing box showed that he had just come home from a botanical excursion. We learn more about this interesting journey from Goethe's *Geschichte meines botanischen Studiums*,[†] and from certain reports from Cohn, in Breslau, which he was able to obtain from a manuscript of Dietrich's. In Karlsbad, conversations on botany now frequently afforded pleasant entertainment. Upon returning home, Goethe devoted himself very energetically to the study of botany; in connection with Linne's *Philosophia*, he made certain observations in regard to mushrooms, mosses, lichens and algae, as we see from his letters to Frau von Stein. Only now, since he has himself thought and observed a great deal, does Linne become more useful to him; through him he finds information in regard to many details which aid him in progressing with his combinations. On November 9, 1785, he reported to Frau von Stein: “I go on reading Linne; I have to, since I have no other book with me. It is the best way to read a book conscientiously, which I must practice more frequently, since I do not easily read a book through to the end. This book was not made for reading, but for recapitulation, and it has done me the most valuable service, since I have thought about most of the points.”

During these studies, it became more and more clear to him that *what appears in the endless multiplicity of single plant individuals is, after all, only one basic form; and this basic form itself became more and more manifest.* He recognized, furthermore, that *this basic form possesses the capacity for endless modifications, whereby manifoldness is created out of* *unity.* On July 9, 1786, he wrote to Frau von Stein: *"It is a becoming aware of the form with which nature, so to speak, always plays, and in playing brings forth manifold life."* What he now needed primarily to do was to develop into a plastic image in its details this enduring, constant element, this primal form with which, so to speak, nature plays. For this there was needed an opportunity to distinguish the truly constant, enduring element in the plant from the changing, unstable element. For observations of this kind Goethe had as yet investigated only a limited region. He had to observe one and the same plant under varied conditions and influences, for only thus does the changeable element become obvious. It is less easily observed in connection with plants of various kinds. All of this was afforded by the fortunate journey into Italy, which he began on September 3, from Karlsbad.

Even in connection with the flora of the Alps, many observations were made. He found there not only new plants which he had never seen, but also such as he already knew, but *modified.* "Whereas in the lower regions, the branches and stalks were stronger and more massive, the buds closer together, and the leaves broad, higher in the mountains the branches and stems were more delicate, the buds farther apart, so that a greater space occurred from joint to joint and the leaves took on a more spear-like shape. I noticed this in the case of a willow and a gentian, and was convinced that they were not different kinds. Also by Walchensee I noticed longer and slenderer rushes than in the lowlands." Similar observations occurred repeatedly. In Venice, he noticed by the sea various plants which showed characteristics that only the ancient salt in the sandy soil, but still more the salt air, could give them. There he found a plant which appeared to him like our "harmless coltsfoot," but armed with sharp weapons and with leaves like leather; the seed capsule also and the stalk were massive and fat. There Goethe saw the instability, the changeableness of all the external characteristics of plants, everything that belongs to their appearance. From this he drew the conclusion that the nature of the plant is not to be found in these characteristics, but must be sought at a deeper level.

It was from observations similar to those of Goethe that Darwin also proceeded when he asserted his doubt as to the constancy of the external forms of genera and species. But the conclusions which the two thinkers reached were entirely unlike. Whereas Darwin considered that the whole nature of the organism was, in fact, comprised in these characteristics, and came to the conclusion, therefore, that there is nothing constant in the life of the plant, Goethe went deeper and drew the inference that, since those characteristics are not constant, what is constant must be sought in something else which lies beneath changeable externalities. To give form to this latter element became Goethe's goal, whereas Darwin's efforts were directed toward searching into and explaining in detail the causes of that changeableness. Both methods of observation are necessary; they supplement each other. It is utterly erroneous to suppose that Goethe's greatness in organic science is to be found in the conception that he was a mere forerunner of Darwin. His mode of observation is far more comprehensive; it embraces two aspects: 1. the Type—that is, the entity of law manifest in the organism, the animality in the animal, the life evolving out of itself, which has the power and capacity, through the potentialities existing in it, to evolve in manifold external forms (species, genera); 2. the reciprocal action between the organism and inorganic nature, and between organisms among themselves (adaptation and the struggle for existence). Only the latter aspect of organics was developed by Darwin. It cannot be said, therefore, that Darwin's theory was the development of Goethe's basic ideas; it was the development of only one aspect of these ideas. It views only those facts which cause the world of living entities to evolve in a certain way, but not that "something" upon which those facts act determinatively. If only one aspect of the problem is inquired into, this can never lead to a complete theory of organisms. The inquiry must really be pursued in the spirit of Goethe; it must be supplemented and deepened through attention to the other aspect of this theory.

A simple comparison will make the matter clearer. Take a piece of lead, reduce it to a fluid by means of heat, and pour it into cold water. The lead has passed through two successive stages in its state of existence; the first was brought about by a higher temperature, the latter by a lower. How the two stages take form depends, not only upon the nature of heat, but essentially also upon the nature of the lead. A different substance, if caused to pass through the same media, would manifest quite different conditions. Organisms likewise are subject to being influenced by the surrounding media; they likewise take on, under the influence of these, various states of existence, and this occurs, indeed, in accordance with their nature, with that essential being which makes them organisms. This essential being is found in Goethe's ideas. Only one who is equipped with an understanding of this entity will be in a position to understand why organisms respond (react) to specific influences in a certain way and in no other. Only such a person will be in a position to form the right conceptions concerning the changeableness of the forms in which the organism appears and the laws of adaptation and the struggle for existence connected with these.

The idea of the archetypal plant took on a constantly clearer and more definite form in Goethe's mind. In the botanical garden in Padua, where he moved about in the midst of a vegetation strange to him, “the thought became more and more alive that it might be possible to develop all plant forms from a single one.” On November 17, 1786, he wrote to Knebel: “Thus, after all, my little bit of botany gives me real joy for the first time in this land, where a happier, less discontinuous vegetation is at home. I have already made quite nice observations tending toward generalizations, which will be agreeable to you also later on.” On February 19, 1787, he wrote in Rome that he was on the way toward “the discovery of new and beautiful relations showing how nature achieves something tremendous that looks like nothing, evolving the manifold out of the simple.” On March 25 he requested that Herder be informed that he would soon be ready with the archetypal plant. On April 17 he wrote down in Palermo regarding the archetypal plant the words: “Surely there must be such a thing; how else could I recognize that this or that form is a plant if all were not formed according to a model?” He had in mind the complex of formative principles which organizes the plant, which makes it what it is, by reason of which we arrive at the idea in regard to a natural object: “This is a plant.” That is the archetypal plant. As such, it is something ideal, to be held fast only in the mind, but it acquires form, it acquires a certain shape, size, color, number of organs, etc. This external form is not fixed, but can undergo endless variations, all of which are in keeping with that complex of formative principles, are derived of necessity from it. If one has grasped these formative principles, that primal image of the plant, one has laid firm hold in idea of that which nature, as it were, lays at the foundation of every single plant-individual, that out of which she calls it forth and causes it to come into existence as a result of this complex of formative laws. Indeed, we can ourselves invent plant forms in accordance with this law, which could follow of necessity and exist through the nature of the plant if the prerequisite conditions should come about.

Goethe thus endeavors, as it were, to reproduce in the mind what nature does in the formation of her entities. He wrote to Herder on May 17, 1787: “Moreover, I must tell you confidentially that I am very close to the secret of the creation of plants, and that it is the simplest thing one could imagine. The archetypal plant will be the strangest creature in the world, which nature herself ought to envy me. With this model and the key to it, one can invent plants endlessly which must be consistent—that is, if they did not exist, yet they could exist, and not some artistic or poetic shadows and appearances but possessing inner truth and inevitability. The same law can be applied to everything living.”

Here becomes apparent a still further difference between Goethe's conception and that of Darwin—that is, especially when one considers how the latter is generally applied. Darwin's view assumes that external influences, like mechanical causes, work upon the nature of an organism and modify it accordingly. To Goethe, the single alterations are various expressions of the archetypal organism (*Urorganismus*), which possesses within itself the capacity to take on manifold forms, and which at a particular time takes on that form which is best suited to the conditions of the external environing world. These external conditions are merely the occasion for the inner formative forces to come to manifestation in a special way. These latter alone are the constitutive principle, the creative element, in the plant. For this reason Goethe called this entity on September 6, 1787, also a *hen kai pan*, a *one and all* of the plant world.

When, now, we consider this archetypal plant itself, the following is to be said about it. The living entity is a whole enclosed within itself, which produces its state of existence through its own nature. Both in the juxtaposition of the members and in the chronological succession of the states of existence of a living entity, there is a reciprocal relationship which does not come to manifestation through a determinative influence of the sensible characteristics of the members, through the mechanical-casual determination of the later by the earlier, but is controlled by a higher Principle, belonging above the members and the states of existence. It is inherent in the nature of the whole that a definite state is fixed as the first and another as the last; and the succession of the intervening states is also determined within the idea of the whole. The preceding is dependent upon the succeeding and vice-versa. In short, in the living organism the evolution of one out of the other, the transition of states one into another, is no ready-made, finished existence of the single entity, but a constant *becoming.* In the plant this determination of each single organ by the whole comes to manifestation to the extent that all organs are built upon the same fundamental model. On May 17, 1787, Goethe wrote this thought to Herder in the words: “It had occurred to me that in the organ of the plant which we ordinarily designate as *leaf*, the true Proteus lay hidden, who can conceal and reveal himself in all forms. Forward and backward, the plant is always only leaf, so inseparably united with the future germ that we cannot imagine one without the other.”

Whereas in the animal that higher Principle which rules over every detail appears concretely before us as that which moves the organs, uses them according to its needs, etc., the plant is without such a *real* life Principle. In its case this reveals itself in the less definite way in that all the organs are constructed according to the same formative type—indeed, that in every part the entire plant is potentially present, and under favorable circumstances could be brought forth out of it. This becomes especially clear to Goethe in Rome as Councillor Reiffenstein, during a walk with him, broke off a twig here and there and asserted that this, if stuck in the ground, must grow, that it must develop to a complete plant. In other words, the plant is an entity which develops in a succession of time intervals certain organs all of which, in relation to one another and also to the whole, are formed according to the same idea. Every plant is a harmonious whole of plants. As this became clear to Goethe, what was still necessary was only to make the individual observations which would render it possible to lay bare in detail the various stages of evolution which the plant sets forth out of itself. For this also what was needed had already occurred. We have seen that, in the spring of 1785, Goethe had made a study of seeds. From Italy he reported to Herder on May 17, 1787, that he had found quite clearly and beyond doubt the point where the germ is concealed. With this he had provided for the first stage of the plant life. But the unity of structure of all the leaves was very soon clearly enough manifest. Along with numerous other examples, Goethe found most especially in the fresh fennel the difference in this regard between the lower and the upper leaves, which are, nevertheless, always the same organ. On March 25, he asked that Herder be informed that his theory of the cotyledons was so refined that it would scarcely be possible to go further. Only a short steps remained to be taken in order to recognize also the petals, the pistils, and the stamens as metamorphosed leaves. The researches of the English botanist Hill could lead to this, which were then generally known and which dealt with the transformation of indivdual flower organs into others.

As the forces which organize the nature of the plant come into actual existence, they take on a series of structural forms. What was now needed was the living concept which united these forms backwards and forwards.

When we consider Goethe's theory of metamorphosis, as it appears from the year 1790, we find that for him this living concept was that of alternate expansion and contraction. In the seed the plant formation is most intensely contracted (concentrated). With the forming of leaves, there follows the first unfolding expansion, of the formative forces. What is pressed together to a point in the seed becomes spatially expanded in the leaves. In the calyx, the forces are again concentrated around an axial point. The corolla is produced by the next expansion. Stamens and pistils come about from the next concentration, the fruit through the last (third) expansion, whereupon the total force of the plant life (this Principle of the entelechy) conceals itself again in the most intensely contracted state in the seed. Although we have thus been able to trace fairly well all the details of the idea of metamorphosis up to its final application in the paper which appeared in 1790, it is not to its final application in the paper which appeared in 1790, it is not as easy to do the same thing with the concept of expansion and contraction. Yet one will not be going astray in assuming that this idea, deeply rooted anyway in Goethe's mind, was also interwoven already in Italy with the concept of plant-formation. Since the content of this idea is the fact of the greater or lesser spatial unfolding determined by the formative forces—and thus exists in that which is directly manifest to the eye in the plant—the idea would surely most easily arise when one undertakes to draw the plant in accordance with the laws of its natural process of formation. Now, Goethe found in Rome a bush-like carnation plant which revealed metamorphosis especially clearly. About this he wrote: “Seeing at hand no means for preserving this wonder-form, I undertook to sketch it exactly, and while doing this I gained more and more insight into the fundamental concept of metamorphosis.” Such sketches were probably often made later and this could then lead to the concept in question.

In September 1787, during his second sojourn in Rome, Goethe expounded the matter to his friend Moriz, and discovered how full of life and how manifest it became through such a presentation. He was always writing down how far he had progressed. It seems probable from this passage and some other remarks of Goethe that even the writing down of the theory of metamorphosis, at least sketchily, occurred in Italy. He says further: “In this way [in the presentation to Moriz] I could get something of my thoughts on paper.” It is beyond question that the work in the form in which it now exists was written down at the end of 1789 and the beginning of 1790. But to what extent this final composition was only editorial in character and what was added will be difficult to say. A book announced for the next Easter season which might, perhaps, contain the same ideas, induced him in the autumn of 1789 to work at his ideas and to arrange for their publication. On November 20 he wrote to the Duke that he had been stimulated to write down his botanical ideas. As early as December 18 he sent the writing to the botanist Batsch in Jena to be examined; on the 20th he himself went there in order to confer with Batsch; on the 22nd he informed Knebel that Batsch had received the thing favorably. He returned home, worked the article over again, and sent it again to Batsch, who returned it on January 19, 1790. What vicissitudes the manuscript, as well as the printed production, then went through Goethe himself has narrated completely. The great significance of the theory of metamorphosis, as well as the essential nature of the theory in detail, will be discussed later in the section entitled *The Nature and Significance of Goethe's Writings on Organic Morphology.*

The above chapter was reprinted from the book *Goethe the Scientist* by Rudolf Steiner, published in 1950 by the Anthroposophie Press, Spring Valley, N. Y. 10977. The material appears with kind permission from the publisher.

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*[*Poetry and Truth*, Goethe's autobiography.

*Karl von Linne, Swedish botanist 1707-1778). Latin name, Linnæus, more commonly used in English.

**The Latest from the World of the Plants.*

†*Selected Microscopic Discoveries in Connection with Plants.*

**Outlines of a Philosophy of the History of Mankind.*

†*History of My Botanical Study.*

BY J. W. GOETHE

INTRODUCTION

1

Anyone who observes even a little the growth of plants will easily discover that certain of their external parts sometimes undergo a change and assume, either entirely, or in a greater or lesser degree, the form of the parts adjacent to them.

2

So the simple flower, for example, often changes into a double one, if petals develop in the place of stamens and anthers. These petals may either perfectly resemble the other petals of the corolla both in form and colour, or they may still retain visible signs of their origin.

3

If we see that in this way it is possible for the plant to make a retrograde step and reverse the order of growth, we shall become all the more aware of the normal course of Nature, and shall learn to understand those laws of transformation by which she produces one part out of another and creates the most varied forms by the modification of one single organ.

4

The secret affinity between the various external parts of the plants, such as leaves, calyx, corolla and stamens, which are developed one after the other and as it were one out of the other, has long been recognised in a general way by naturalists; indeed, much attention has been given to the study of it. The process by which one and the same organ presents itself to us in manifold forms has been called the *metamorphosis of plants.*

5

There are three kinds of metamorphosis: *regular, irregular* and *accidental.*

6

Regular metamorphosis we may also call progressive, for here we may follow the development step by step from the first seed-leaves to the final forming of the fruit, ascending through transformations of one form into another, as by a spiritual ladder, to that crowning aim of Nature, the propagation of the plant by male and female organs. I have been attentively observing this process for some years, and it is in order to explain it that I am writing now. In the following demonstration we shall therefore study the plant only in so far as it is annual and proceeds without pause from the seed to fertilisation.

7

Irregular metamorphosis may also be called *retrogressive*. For as in the former case Nature hastens forward to her great aim, here she takes one or more steps backward. In the former instance, with irrestible impulse and powerful effort she forms the flowers and fits them for the service of love; in the latter she seems as it were to relax, and irresolutely leaves her creation in an indefinite and soft state, often pleasing to the eye, but intrinsically powerless and inactive. Frequent experience of this kind of metamorphosis will enable us to disclose what in the regular way of development is hidden from us, and to see clearly and visibly what we should otherwise only be able to infer. In this way we may hope to attain our purpose with the greatest possible certainty.

8

The third kind of metamorphosis, on the other hand, which is brought about accidentally by external causes, and especially by insects, we shall not take into consideration; it might lead us astray from the simple path we have to follow and delay the attainment of our object. Perhaps an opportunity will be found elsewhere to speak of these growths; monstrous they are, yet confined within certain limits.

9

I have ventured to publish this attempt without explanatory illustrations necessary as they might seem in some respects. I may introduce them later; this can easily be done as sufficient material still remains for elucidating and enlarging this short and preliminary treatise. It will not then be necessary to keep so measured a step as now. I shall be able to produce much that relates to the subject, and numerous quotations from authors holding similar views will appear in their right place. Above all I shall not fail to make use of observations gathered from those contemporary masters of whom this science can boast. To them I present and dedicate these pages.

CHAPTER I
OF THE SEED-LEAVES

10

As we have set out to observe the successive steps in the growth of the plant we will begin by directing our attention to it when first it develops out of the seed. At this stage the parts which directly belong to it are easily and exactly distinguishable. It leaves its sheathes more or less behind in the earth; these we will not examine now. Then in many cases, when the root has fastened itself in the soil, the plant brings to the light the first organs of its upper growth, which were already there, hidden under the seed-coat.

11

These first organs are known as cotyledons; they have also been called seed valves, kernel pieces, seed-lobes, or seed-leaves, in the attempt to name them according to the different forms in which we find them.

12

They often appear unshapely, stuffed as it were with a crude substance and distended as much in thickness as in width. Their vessels are unrecognisable and scarcely to be distinguished from the mass of the whole, and they have hardly any resemblance to a leaf, so that we might be misled into believing them to be special organs.

13

Yet in many plants they approach the shape of a leaf; they become flatter, and when exposed to light and air they assume a deeper green, and the vessels contained in them become more recognisable, more like leaf-veins.

14

Finally they sometimes even take on the appearance of real leaves. Their vessels are then capable of high development, and their resemblance to the subsequent leaves does not permit us to regard them as distinct organs; we have to recognise them as the first leaves of the stem.

15

Now as we cannot conceive of a leaf without a node or of a node without an eye, we may conclude that the point at which the cotyledons are attached is the first true node of the plant. This view is confirmed by those plants which produce young eyes immediately under the wings of the cotyledons, and from these first nodes develop complete branches, as, for example, is the case with the common bean, *Vicia Faba*.

16

The cotyledons are usually double; and here we have a remark to make which will appear to us of still greater importance later on. Namely, the leaves of this first node often appear in pairs, even when the subsequent leaves of the stem are placed alternately. Here then is shown a coming together and uniting of parts which Nature later separates and places at a distance one from the other. Still more remarkable is it when the cotyledons appear like many little leaves gathered round a single axis, while the stem which gradually develops out of their midst produces the subsequent leaves singly around itself. This may be very well observed in the growth of the different kinds of pine; where a wreath of needles forms as it were a calix. As we proceed we shall be reminded of this in other similar phenomena.

17

For the present we will pass over the quite shapeless single cotyledons of plants which germinate with one leaf only.

18

Let us remark, however, that even the most leaf-like cotyledons, in comparison with the subsequent leaves of the stem, are always less developed. Above all their margin is extremely simple, with as few traces of incisions in it as there are of hairs on the surface, or of any of those vessels which are to be observed in perfect leaves.

CHAPTER II

THE DEVELOPMENT OF THE STEM-LEAVES FROM NODE TO NODE

19

We are now able to observe closely the successive formation of the leaves, as the progressive operations of Nature all take place before our eyes. Some, or many, of the leaves which now appear are often already present in the seed and lie enclosed between the cotyledons; in their folded state they are called plumules or “little feathers.” Their shape, compared with that of the cotyledons and of the future leaves, varies in different plants, but they usually differ from the cotyledons in that they are flat, delicate and formed altogether like real leaves; they become entirely green, they are attached to a visible node and their relation to the following stem-leaves can no longer be denied. They are, nevertheless, inferior to them in so far as their periphery or margin is not yet perfectly formed.

20

Henceforward the further development of the leaf progresses without pause from node to node; the vein lengthens out and the veins that branch out from it extend more or less towards the edge. These different relationships of the veins to one another are the primary cause of the manifold leaf-shapes. The leaves may appear notched, deeply-incised, or formed of many leaflets joined together, in which case they resemble perfect little twigs. The date palm affords a striking example of the simplest type of leaf developing into the most manifold forms. As the leaves succeed each other the central vein grows more and more prominent, the fan-like and yet simple leaf becomes torn and divided and an extremely compound, branchlike leaf is formed.

21

The development of the leaf-stalk keeps pace with that of the leaf. The two are either intimately connected or the stalk forms a special little stem which at long last is quite easily detached from the leaf as such.

22

That this independent leaf-stalk also has a tendency to change into the form of a leaf, is disclosed by a variety of plants, the *Agrumae* for example. The organization of the leaf-stalk, which for the present we will pass over, will prompt us to further considerations in the future.

23

Neither can we for the moment enter upon a closer examination of bracts and stipules. We can only observe in passing that, especially when they constitute a part of the leafstalk, they share its future transformations in many remarkable ways.

24

While the leaves owe their first nourishment principally to the more or less modified watery parts which they draw from the stem, for their increased perfection and refinement they are indebted to the light and air. The cotyledons which are formed beneath the closed seed-sheath are charged, so to speak, with only a crude sap, they are scarcely or but rudely organised and quite undeveloped. In the same way the leaves are more rudely organised in plants which grow under water than in others which are exposed to the open air. Indeed, even the same species of plant develops smoother and less intricately formed leaves when growing in low damp places, while, if transplanted to a higher region, it will produce leaves which are rough, hairy and more delicately finished.

25

So also the anastomosis of the vessels which spring forth from the larger veins, seeking each other with their ends and coalescing, and thus providing the necessary basis for the leaf-skin or cuticle, if not entirely caused by subtle forms of air, is at least very much furthered by them. If the leaves of many water-plants are thread-like or assume the form of antlers we are inclined to attribute it to a lack of complete anastomosis. The growth of the water buttercup, *Ranunculus aquaticus*, shows us this quite obviously, with its aquatic leaves consisting of mere thread-like veins, while in the leaves developed above water the anastomosis is complete and a connected plane is formed. Indeed, occasionally in this plant, the transition may be still more definitely observed, in leaves which are half anastomosed and half thread-like.

26

Experience has taught that the leaves draw in various kinds of air which they combine with the moisture contained within them, and there is no doubt that they bring these more refined juices back again into the stem, and so greatly promote the development of the adjacent eyes. This has been ascertained by examining the kinds of air developed in the leaves of many plants, and even in the cavities of hollow stems.

27

We observe in many plants that one node spring from the other. In the stems of the cereals, grasses and reeds, which are closed from node to node, this is obvious; but it is not so obvious in plants whose centre is hollow throughout or filled with pith, that is, with loose cellular tissue. But the supposed important functions of the pith or “marrow” being now on good ground called into question, and the impulsive and productive power once claimed for it being today attributed to the inner side of the second rind, the so-called cambium, we can now more easily understand that a more highly situated node, developing as it does from a preceding one and receiving the juices from it in a finer and more highly filtered condition, benefits from the operation of the intervening leaves and will therefore develop all the more perfectly and in its turn transmit more elaborated juices to its own leaves and eyes.

28

In so far as the fluids are in this way constantly drained away and purer ones introduced, and the plant gradually develops into a more perfect condition, it attains the end ascribed to it by Nature. At length we see the leaves perfectly developed in size and form, and soon become aware of a fresh phenomenon, which tells us that the period we have observed so far is over, and that a second one is approaching, namely that of the flower.

CHAPTER III
TRANSITION TO THE FLOWER

29

The transition to the flowering condition takes place with greater or lesser rapidity. In the latter case we shall usually notice that the stem-leaves begin to contract once more from the periphery inward, and especially to lose their manifold outer incisions. On the other hand, they tend to spread out more or less where with their lower parts they are attached to the stem. At the same time we see that the spaces between the nodes of the stem become, if not perceptibly longer, at least more slender and more delicately formed in comparison with the preceding state.

30

It has been observed that copious nourishment hinders the flowering of a plant, while moderate or even scanty nourishment accelerates it. In this we see still more clearly the function of the stem-leaves which we have already been considering. As long as there are cruder juices to be drained away, the plant must continue to develop the necessary organs to carry out this task. If superfluous nourishment is forced on the plant, this task must be continued, and flowering becomes almost impossible. But if excessive nourishment is withheld, Nature's operation is rather hastened and facilitated, the organs of the nodes become more refined, the unadulterated juices act more purely and more strongly. In a word, the metamorphosis of parts is made possible and takes place without delay.

CHAPTER IV

FORMATION OF THE CALYX

31

We often see this change taking place quickly; when this is so the stem shoots upward all at once from the node of the last developed leaf and becomes tapering and more delicate, ending in a little collection of leaves around an axis.

32

There seems to us to be quite clear proof that the leaves of the calyx are the same organs as those which we have so far seen developing into stem-leaves, only now they are collected—often in a very changed form—round a common centre.

33

We have already noticed a similar operation of Nature in the cotyledons, where several leaves—nay more, obviously several nodes—are gathered close to one another round a single point. The pine species in their development from the seed show a rayed circle of unmistakable needles which, in comparison with other cotyledons, are highly developed. When this plant is still quite young we can already see an indication, as it were, of that force of Nature which at a more advanced age will produce the blossom and fruit.

34

Furthermore, in many flowers we see unaltered stem-leaves collected together so as to form a kind of calyx just below the flower. As their form is still quite unchanged we can recognise that they are leaves by their appearance, and indeed in the botanical terminology they are called “flower leaves”—*folia floralia.*

35

With great attention we must watch the procedure in the case already mentioned when the transition to the flowering period takes place slowly; the stem-leaves gradually draw together, become modified and pass almost unawares into calyx-leaves. This may readily be seen in the compositae, especially in sunflowers and marigolds.

36

This force of Nature which collects a number of leaves around a single axis can bring about a still more intimate union, making the clustered and modified leaves more than ever difficult to recognise. The calyx-leaves or sepals are then joined together—either entirely so, or only partly grown together at the edges. These leaves, crowded and closely pressed to one another, touch most intimately while in their tender state. They become anastomosed under the influence of the very pure juices now present in the plant, and form the bell-shaped or so-called one leaved calyces revealing their composite origin by the way in which they are more or less incised or divided. We shall learn this if we compare a number of deeply incised single calyces with many-leaved ones and especially if we observe the calyces or involucres of some compositæ. Thus, for example, we shall see that the calyx of a marigold, which is defined in systematic descriptions as "simple and much-divided," consists of several leaves grown into and over one another, into which, as we have already said, the contracted stem-leaves imperceptibly pass over.

37

In many plants the number and form in which the calyx-leaves or sepals, whether single or grown together, are arranged around the axis of the stalk, is constant, and this is also the case with the other subsequent parts. On this constancy rests to a great extent the progress, certainty and reputation of botanical science, which in recent years has been making continual advances. In other plants, the number and formation of these parts is not so constant, yet even this inconstancy has not escaped the keen powers of observation of the masters of this science; on the contrary, they have tried, by means of exact definitions, to restrict even this variation of Nature, as it were into some pattern of conformity.

38

Thus has Nature formed the calyx, by uniting—around a common centre, and as a rule in definite number and order—many leaves and consequently many nodes which she would otherwise have produced one after the other and at some distance apart. If the flowering period had been retarded by the in-streaming of superfluous nourishment, the nodes and leaves would have appeared separated from one another in their original form. Nature, therefore, in forming the calyx creates no new organ, but simply combines and modifies the organs we already know, advancing in this way a step nearer her goal.

CHAPTER V

FORMATION OF THE COROLLA

39

We have seen how the calyx is produced through the influence of refined juices gradually generated in the plant, and now the calyx itself is destined to become the organ of a future and further degree of refinement. We can believe this even if we explain its operation from a purely mechanical point of view. How tender and capable of the finest filtration must be the vessels which are so highly contracted and drawn together!

40

The transition from the calyx to the corolla can be seen quite clearly, for although the calyx is usually green like the stem-leaves, it often shows a change in one part or another at the tips, the edges, the back or even over the inner surface, leaving the outer surface green. Also whenever this colouring occurs we see it combined with an increased refinement of texture. Thus there arise the calyces which we should be equally justified in regarding as corollas.

41

We have observed from the seed-leaves (cotyledons) upward a process of great expansion and development of the leaves to the periphery, while in the transition to the calyx we see once more a contraction from the circumferance towards the centre. We now notice that the corolla is produced by yet another expansion. The petals are usually larger than the calyx-leaves or sepals. Even as the organs were contracted into the calyx, so do they now expand again into petals under the influence of the still more finely filtered juices which have passed through the calyx to appear in a highly refined state as new and quite different organs. Their delicate organisation, their colour and their scent would make it quite impossible to recognise their origin if we were not able to hearken to Nature as she speaks to us through her many vagrancies and abnormalities.

42

Thus, for instance, inside the calyx of a carnation a second calyx is often found which on the one hand, inasmuch as part of it is quite green, reveals its tendency to become a one-leaved, incised calyx, while on the other hand it is tom and jagged and beginning at the tips and edges to expand

and to become tinted like the real petals. Through this we clearly recognise the relationship between the corolla and the calyx.

43

The relation of the corolla to the stem-leaves reveals itself in different ways. On many plants the stem-leaves are produced more or less coloured long before they approach the flowering state; in other cases they become completely coloured when they get near to the flower.

44

Sometimes, too, Nature proceeds immediately to the corolla, omitting the calyx altogether and we are given the opportunity of observing the transformation of stem-leaves into petals. On tulip stalks, for example, an almost perfectly formed and coloured petal may sometimes be seen. Indeed it is even more remarkable when such a leaf, half green and half coloured, belongs with its green part to the stem and remains attached thereto, while its coloured part is carried up into the corolla so that the leaf is torn in two.

45

It is a not unlikely opinion which would ascribe the colour and scent of the petals to the presence of the male seed within them. It may be there in an insufficiently separated state, combined with and diluted by other juices. The mani-

45

fold and beautiful appearances of colour incline us to the thought that the substance contained in the petals, although it is in an extremely purified condition, has not yet attained the very highest degree of purity, which would be white, absolutely without shade or colour.

CHAPTER VI

THE FORMATION OF THE STAMENS

46

The opinion set forth in the preceding paragraph appears still more probable when we think of the near relationship of the petals with the stamens. If the relationship between all the other organs were so obvious, so generally noticed and set beyond doubt, the present essay might seem superfluous.

47

Nature shows us this transition between petals and stamens taking place normally in several instances, in *Canna*, for example and in other plants of this family. Here a true but slightly changed petal contracts at the upper edge and an anther appears, in relation to which the rest of the petal takes the place of the filament.

48

In those plants which often produce double blossoms we can observe this transition in all its stages. In many kinds of roses, among the perfectly formed and coloured petals, other petals may appear which are contracted partly in the middle and partly at the sides. This contraction is caused by a little weal or protuberance which more or less resembles a perfect anther, while in just the same proportion the petal begins to take on the simpler form of a stamen. In some double poppies, fully developed anthers rest on petals of the thickly filled corolla which are very little changed; in others the petals are more or less drawn together by anther-like weals.

49

If all the stamens change into petals the flower will be seedless, but if in a flower which appears double, stamens are still developed, then fertilisation will take place.

50

Thus a stamen is produced when the organs, which until now we have seen expanding into petals, reappear in an extremely contracted and at the same time refined state. This once more confirms the truth of the observation put forward above, and we are made more and more aware of the alternating process of contraction and expansion whereby Nature at last reaches her goal.

CHAPTER VII
NECTARIES

51

Quick as the transition is in some plants from the corolla to the stamens, we perceive that Nature is not able to complete it in one step, but produces intermediate organs which resemble in form and effect sometimes one part of the plant and sometimes another. Although they vary greatly in form these organs may mostly be united under one heading: they are slow transitions from the petals to the stamens.

52

In effect, most of those variedly formed organs, which Linnaeus called nectaries, may be thus defined, and here again we have occasion to admire the keen power of penetration of this extraordinary man, who, without coming to a perfectly clear understanding of the function of these parts, trusted to his intuitive feeling and ventured to give a single name to such seemingly different organs.

53

Various petals show us their relationship to stamens; without noticeably changing their form they have little cavities or glands which secrete a kind of honey-juice. That this juice is a yet unelaborated and not yet fully differentiated fertilizing fluid we can to some extent surmise from the above considerations, and we shall be supported in this by further reasons which will be brought forward later on.

54

The so-called nectaries may also appear as independent organs and then they are formed sometimes like petals, sometimes like stamens. Thus, for example, the thirteen filaments, each with its little red ball, on the nectaries of *Parnassia*, very much resemble stamens. Others look like stamens without anthers, as for example in *Valisneria* or *Feuillea*, while in *Pentapetes* we find them in a circle alternating regularly with the stamens and in leaf-like form. In systematic descriptions too these organs are called *Filamenta castrata petaliformia*. Similar ambiguous forms are to be seen in *Kigellaria* and the Passion-flower.

55

In this sense the “secondary corollas” seem likewise to deserve the name of nectaries. For if the forming of the petals comes about through a kind of expansion, the secondary corollas on the other hand are formed by contraction, that is to say, in just the same way as the stamens. And so we see within perfectly expanded corollas smaller, contracted, secondary ones, as for example in the *Narcissus, in Nerium* and in *Agrostemma.*

56

Furthermore, in various species we see alterations which are still more striking and remarkable. In some flowers we notice a little hollow filled with honey-like juice at the inner base of the petals. This little cavity becomes deeper in some species and types than in others and produces on the back of the petal a spur or horn-like protuberance, the shape of the rest of the petal being at the same time more or less modified. This can be distinctly seen in many types and variations of *Aquilegia.*

57

We find the nectary most transformed in *Aconitum* and in *Nigella,* but even here only a little attention will enable us to see its resemblance to a leaf. In *Nigella* especially it tends to grow into a leaf or petal and through the transformation of the nectaries the flower becomes double. In *Aconitum* it is easy to see the resemblance of the nectaries to the domed-shaped petals under which they are hidden.

58

Having already said that the nectaries are a transitional stage between petals and stamens we may at this point say a few words about irregular flowers. The five outer petals of *Melianthus,* for example, could be described as true petals, but the five inner ones as a secondary' corolla consisting of six nectaries, of which the uppermost nearly resembles the leaf-form while the lower—which is indeed called the nectary—differs most from it. In this same sense the *carina* or keel of the Papi-lionaceae might be called a nectary in so far as it, of all the petals of this flower, is nearest in form to the stamens and differs greatly from the leaf-like form of the so-called *vexilli.* In this way too we may easily explain the brush-like appendages which are attached to the end of the *carina* of some species of *Polygala*: so shall we form a distinct idea of the real meaning of these organs.

59

It is hardly necessary to avow that these remarks are not intended to bring into confusion all that has hitherto been separated and classified through the endeavours of observers and systematists. We only wish to explain more clearly the variable formations and developments of the plant-kingdom.

CHAPTER VIII

MORE ABOUT THE STAMENS

60

Microscopic observations have placed it beyond doubt that the generative organs of the plants as well as other organs are produced by spiral vessels. We take this as a basis for the argument that the different parts of the plant, which have so far manifested themselves to us in such varied forms, are none the less intrinsically the same.

61

Now as the spiral vessels are situated in the middle of the bundles (vascular bundles) and are enclosed by them, we can to some extent come to a better understanding of the above-mentioned strong contracting force if we imagine the spiral vessels, which really look like elastic springs, exerting their utmost power so that they overcome the expansive tendency of the sap-vessels.

62

The shortened vascular bundles can then no longer expand; they are not able to unite so as to form a network by anastomosis, and the cellular tissue, which otherwise fills up the spaces of the network, can no longer develop. Here, all the causes for the expansion of stem-leaves, calix and petals are at an end, and there appears a frail, extremely simple thread or filament.

63

Hardly are the fine little membranes of the anther formed, than the extremely delicate vessels terminate in them. Now if we admit that here the very same vessels, which otherwise become lengthened and expanded and united with one another, are at this stage in an extremely contracted condition; if, moreover, we see coming from them the highly developed pollen which through its active energy compensates for what the vessels that have brought it forth have lost in their power of expansion; if when set free it seeks the feminine parts which through the same working of Nature have grown up near the stamens; if it attaches itself fast to the pistils and imparts its influence to them—then at long last we are not disinclined to call the union of the male and female organs a *spiritual anastomosis*, and we believe we have brought the concepts of growth and reproduction, at least for a moment, a little nearer to one another.

64

The fine substance, which is developed in the anthers, looks like a kind of dust; but these little balls of pollen are in fact vessels or cells for the preservation of an extremely refined juice. We agree with the opinion of those who maintain that this juice is absorbed by the pistils to which the pollen-balls attach themselves, fructification being in this way effected. This becomes even more credible when we think that some plants do not give off pollen grains, but only a kind of fluid.

65

We are here reminded of the honey-like juice of the nectaries and its probable relation to the more elaborated fluid of the pollen grains. Perhaps the nectaries are organs for preparation and maybe their honey-like moisture is drawn in by the anthers and then more fully perfected and elaborated—quite a plausible opinion, for this sap is no longer to be seen after fructification.

66

We will not omit to mention here in passing that the filaments as well as the anthers, grow together in many different ways, showing what we have so often described, namely the anastomosis and union of organs which in their beginnings were quite apart and distinct.

CHAPTER IX

FORMATION OF THE STYLE AND STIGMA

67

If until now I have tried to show as far as has been possible that the different parts of the plant as they develop one after the other, even though they may greatly differ in outward form, are intrinsically the same, it will easily be surmised that my aim will now be to explain in this way too the structure of the feminine parts.

68

At first we will consider the style and stigma of the pistil apart from the actual ovary, as indeed, we often find it in Nature. This we may the more easily do, as it reveals a characteristic and distinct form.

69

We observe then, that the pistil is at the same stage of growth as the stamens. We noticed that the stamens were produced through a contraction; this is also often the case with the styles, and we see that, though not always just the same length as the stamens, yet they are only a little longer or shorter. In many cases the style looks almost like a filament without an anther, and the two are more nearly allied in exterior form than any of the remaining parts. As they are both produced by spiral cells, we see all the more clearly that the feminine part is no more a distinct organ than the masculine part, and when through this observation the close relationship of these feminine parts with the masculine becomes evident to us, we find it all the more appropriate and illuminating to think of their union as a kind of anastomosis.

70

We very often find the pistil formed by the growing together of several single ones, the component parts being hardly distinguishable at the tip, where they are not even separated. This growing together, the effect of which we have often remarked upon, takes place in this instance most easily of all. Indeed, it must happen, for the delicate organs, before they are perfectly developed, are pressed together in the blossom and thus enabled intimately to unite with one another.

71

In various normal cases Nature shows us more or less clearly the near relationship of the pistil with the preceding parts of the blossom. For example, the pistil of the iris appears with its stigma in the perfected form of a petal. The umbrella-shaped stigma of *Sarracenia* shows that it is composed of several leaves set together. True, this is not so marked and yet even the green colour is retained. With the help of the microscope we find more stigmas formed like perfect one- or many-leaved calyces in the crocus, for example, or *Zannichellia*.

72

By a retrogressive development Nature often shows us instances where the style and stigma have changed back again into petals; the *Ranunculus asiaticus*, for example, becomes double in this way, the stigmas and styles having transformed themselves into true petals, while the anthers, immediately underneath, may often be found unchanged. One or two other remarkable instances will come to our attention later on.

73

We will here repeat the observations already made: that pistil and the stamens are at the same stage of growth and illustrate once again the fundamental principle of alternate expansion and contraction. From the seed to the most perfect development of the stem-leaf we first observe expansion; then we saw the calyx being formed through a contraction; the petals by expansion; the reproductive organs again by contraction; and now we shall soon become aware of the greatest expansion and contraction of all, namely the expansion in the fruit and the contraction again in the seed. In these six steps Nature continually completes her endless work of the propagation of plants by the two sexes.

CHAPTER X
THE FRUITS

74

It is now the fruit which we have to observe, and we shall soon be convinced that this too originates in the same way as the previous parts and is subject to the same laws. We speak here really of those vessels or capsules formed by Nature to enclose the so-called covered seeds, or rather to develop through fructification within these vessels a greater or lesser number of seeds. It will be easy to show that these vessels may likewise be explained according to the nature and organisation of those parts of the plant we have already considered.

75

It is once more the retrogressive metamorphosis which brings to our notice this law of Nature. We may often observe in pinks, for example—which just because of this irregularity are such well-known and favourite flowers—that the seed capsules transform again into leaves like those of the calyx, and that in just the same proportion the styles become shorter. Indeed, it even happens sometimes that the fruit capsule of a pink transforms into a real and perfect calyx, the divisions of which still have tender remnants of styles and stigmas attached to them, while from the very centre of this second calyx a more or less perfect corolla develops instead of seeds.

76

Furthermore even in normal and constant formations Nature reveals in manifold ways the fruitfulness that lies hidden in the leaf. Thus a leaf of the lime—a somewhat changed leaf, it is true, but none the less quite recognisably a leaf—produces from its middle vein a little stalk and on it a perfect blossom and fruit. In *Ruscus* this manner in which the blossom and fruit rest on the leaf is still more remarkable.

77

Still greater—we may even say monstrous—is this inherent fruitfulness of the leaf as shown to us in ferns. Through an inner impulse, and perhaps even without the direct operation of two sexes, they develop and scatter around innumerable seeds, or tiny germs, capable of growth, so that a single frond rivals a wide-spreading plant in fruitfulness, or even a large branching tree.

78

If we keep observations in mind we shall not fail to recognise the leaf-form in all seed-vessels, in spite of their manifold formations, their peculiar modifications and combinations. So for example, many pods may be regarded as a single leaf, folded and grown together again at the edges; others again consist of several leaves grown one upon another; compound pods or capsules may be explained as composed by several leaves united around a common centre, joined at their edges but open towards one another on their inner sides. We are convinced of this even by visual demonstration when such capsules, having become set together, burst apart after the ripening of the seed, so that each part shows itself to be an open pod or shuck. We also see, in various types of one and the same species, a similar process taking place normally; for example, the fruit capsules of *Nigella orientalis* are formed of pods partly grown together and collected round an axis, while in *Nigella damascena* they are completely united.

79

Nature conceals this likeness to the leaf-form most when she forms soft and juicy or hard and woody seed-vessels. **But** even then it will not escape our notice if we know how to follow this development carefully through all its transitions. Here it is enough to have indicated the general idea and to have shown by means of a few examples Nature's unity of purpose. The manifold varieties of seed-capsules will afford us material for future and further consideration.

80

The relation of seed-vessels to the preceding parts is also made apparent in the stigma, which in many cases sits immediately upon the ovary and is inseparably united with it. We have already shown the relation of the stigma to the leaf-form and can mention it once again as it may be seen in double poppies, where the stigmas of the seed-capsules are changed into delicate coloured petals—quite true leaf-forms.

81

The last and greatest expansion effected by the plant in the course of its growth comes to expression in the fruit. It is often great, even monstrous, both in internal strength and external form. As it usually grows bigger after fertilisation it would seem that the now more fully determined seed that is to be, while drawing the juices needed for its growth from all parts of the plant, directs them mainly to the seed-covering— or fruit—whereby the vessels of the latter are nourished, enlarged and often to a very great extent filled out and distended. It may be inferred from what has already been said that purer forms of air have had a great share in this, and experiment has shown that the swollen pods of *Colutea* contain pure air.

CHAPTER XI

THE IMMEDIATE COVERING OF THE SEED

82

On the other hand we find in the seed itself the highest degree of contraction and inner perfection. It may often be observed that the seed transforms leaves into its immediate covering, adapting them more or less to its shape and indeed usually having the power to attach them fast to itself, entirely changing their form. Having already seen that many seeds may develop from and within a single leaf, we shall not wonder that a single embryo should clothe itself in a leaf covering.

83

We see in many winged seeds traces of such leaf-forms not perfectly fitted to the seed— for example, the maple, the elm, the ash and the birch. A very remarkable example of the way in which the rudimentary seed gradually draws together wider coverings and adapts them to its own size is given to us us by the pot marigold, with its three circles of differently formed seeds. The outermost circle retains a form related to the leaflets of the involucre, except that a rudimentary seed, causing the vein to buldge, makes the leaf curved; the inner side of this curved surface is then divided along its length into two parts by a membrane. The next circle has become even more changed; the width of the leaf and the membrane have quite disappeared; on the other hand the form has lengthened to a lesser degree and the rudimentary seed is more plainly visible at the back, the little mounds more defined. Both of these rows seem either not at all or only imperfectly fructified. Then follows the third circle of seeds, in their true form—very rounded and with a completely fitting covering, fully developed with all its little mounds and ridges. We see once more the powerful contraction of expanded leaf-like parts, brought about moreover through the inner power of the seed just as before we saw the petal contracted through the power of the anther.

CHAPTER XII

A GLANCE BACKWARD AND FORWARD

84

So we have followed Nature's footsteps as thoughtfully as may be: we have traced the outward form of the plant in all its transformations—from the development out of the seed until the seed is formed once more—and, without wishing in arrogance to probe the hidden springs of impulse in Nature's operations, we have directed our attention to the outward manifestations of those powers through which the plant, step by step, transmutes one and the same organ. In order not to abandon the thread once taken up, we have all the time been considering only annual plants. We have simply observed the transformation of the leaves which accompany the nodes and from them have deduced all varieties of form. All that now remains to be done, in order to give this attempt its necessary completeness, is to speak of the eyes which lie hidden beneath each leaf and develop under certain circumstances while under others they seem completely to disappear.

CHAPTER XIII
EYES AND THEIR DEVELOPMENT

85

Every node has by nature the power to produce one or more eyes. They appear close to the accompanying leaves, which seem to prepare and to help their formation and growth.

86

On the successive development of one node out of another and on the formation of a leaf at every node and an eye close by it, rests the first simple, slow process of growth by which vegetable life is propagated.

87

It is well known that such an eye is very like a ripe seed in its working, and that often in the eye, more easily than in the seed, the entire form of the future plant may be recognised.

88

Even though the point at which the root will be developed is not so easily detected in the eye, yet it is there, just as it is in the seed, and develops quickly and easily, especially under the influence of moisture.

89

The eye does not need cotyledons, because it is connected with the parent plant which, now completely organised, provides sufficient nourishment as long as this connection lasts. After separation the bud is nourished either by the new plant on which it has been grafted, or by means of the roots which it forms immediately when planted in the soil.

90

The eye consists of nodes and leaves in a more or less developed condition, destined to enlarge and expand the growing plant.

In effect, the side twigs which sprout from the nodes may be regarded as distinct little plants, growing on the parent plant just as the latter grows in the earth.

91

The comparison of seed and eye has so often been made, and especially quite recently, with such penetration and exactitude, that we can but appeal to this work with unqualified approbation.

92

We will only state the following: In highly organised plants nature makes a clear difference between eyes and seeds. In more simply formed plants, however, this difference no longer seems apparent, even to the most acute observer. There are seeds which are undoubtedly seeds, and eyes which are undoubtedly eyes, but it is only possible to conceive, and not in any outward way to see, where the line of demarcation lies between properly fertilised seeds, separated from the parent plant by the reproductive process, and propagative buds which simply push their way out from the parent plant and separate from it without any apparent cause.

93

Having weighed this well in our minds we may venture to think that seeds, though they differ from eyes by being completely enclosed, and from propagative buds by the visible cause of their formation and separation from the parent plant, are yet closely related to both.

CHAPTER XIV

FORMATION OF COMPOSITE FLOWERS AND FRUITS

94

We have so far tried to explain by the transformation of the stem-leaves, the formation of single flowers and also seeds produced within a closed capsule. Closer examination will show that in these instances no eyes are developed; indeed there is absolutely no possibility for such a development to take place. To understand the composite flower however, as well as the compound fruit gathered around a single cone, spindle, dies or the like, we must look to the development of eyes.

95

We often see that stems, without preparing long beforehand or reserving their energy for the development of a single flower, bring forth blossoms already at their nodes, often continuing in this way uninterruptedly to the very tip. This may be explained however by the theory already propounded. All flowers developed from eyes may be regarded as distinct plants growing on the parent plant, just as the parent plant grows on the earth. Supplied, however, as they are with purer juices by the nodes, even the first leaves of the little twigs are much more finely formed than the first leaves of the parent plant which came after the cotyledons; indeed, even the immediate formation of calyx and flower is often possible.

96

Even these blossoms that develop out of eyes, had they received more copious nourishment, would have become twigs and have undergone a destiny similar to that of the parent plant.

97

During the development of such flowers from node to node, we notice too that same transformation of the stem-leaves which we observed when the transition to the calyx took place slowly. The leaves contract more and more, until at last they almost disappear. They are then called bracts, and have more or less lost their leaf-like form. Just in the same proportion as the stem becomes thinner, so do the nodes move closer together, and everything that happened in the transition to the calyx happens now, except that no particular terminal flower appears at the tip, because Nature has already fulfilled her task at each successive eye.

98

Now when we have contemplated well such a stem adorned at each node with a blossom, we shall more easily understand a composite flower, especially if we remember what has already been said about the origin of the calyx.

99

Nature forms a composite calyx, (involucre) from a number of leaves by pressing them close to one another and arranging them around an axis. With this same strong impulse of growth she develops, so to speak, one infinite stem, producing all its eyes at the same time and as near together as possible in the form of a flower, each separate floret fructifying the seed-vessel already prepared below it. Nor are the nodal leaves always entirely lost in this tremendous contraction. In thistles for example (compare *Dipsacus laciniatus*), the little leaf faithfully accompanies the floret which grows from the eye situated close by it. In many grasses, too, each flower has such a leaflet, which in this case is called a glume.

100

So we are led to see that the seeds of a composite flower are true eyes, formed and developed by means of the male and female organs. We shall easily be convinced that this is so if, keeping this idea always in mind, we examine and compare the growth and manner of seeding of various plants.

101

Then, too, we shall not find it difficult to explain the seeds—whether enclosed within a seed-vessel or not—which are produced in the middle of a single flower. For it comes to the same thing if a single flower surrounds a compound ovary, whose united pistils suck in the fertilising juices from the anthers and pass them on to the ovules, or if each ovule has its own pistil, and anthers and petals.

102

We are convinced that with a little practice it would not be difficult to explain in this way the manifold forms of flowers and fruits. But it would of course require complete familiarity with the above stated ideas of expansion and contraction, approximation and anastomosis, to be able to apply them in their right place as one would use algebraic formulae. And as much depends on the exact observation and comparison of the various stages through which Nature passes, both in the forming of genera, species and varieties, and in the growth of each individual plant, a collection of illustrations made for this purpose with explanations of the different parts of the plant in botanical terminology would be both welcome and useful. Two strange instances of proliferous flowers, if we could have them before us, would help most decidedly in upholding this theory.

CHAPTER XV

A PROLIFEROUS ROSE

103

All that we have been seeking to grasp by powers of imagination and thought is shown most clearly in the instance of the proliferous rose. The calyx and corolla are arranged and developed around the axis; but instead of the seed-vessel contracted in the centre of the blossom, with the masculine and feminine organs arranged around, the stem, half red and half green, continues upward, while from it arise in succession smaller, dark red, folded petals, some of them bearing traces of anthers. The stem goes on growing, thorns appear on it again, the coloured petals which now appear singly become smaller and at last transform into variegated stem-leaves, half red and half green; a series of regular nodes is formed and from their eyes small, though imperfect, rosebuds appear once more.

104

This example in particular affords visible proof of our theory, namely, that all calyces are simply leaves, *folia floralia*, contracted and growing together at the periphery. For in this specimen the calyx, gathered round the axis, consists of five perfectly developed, compound leaves of three or five leaflets, such as are normally produced by rose branches at their nodes.

CHAPTER XVI

A PROLIFEROUS CARNATION

105

Strange as this phenomenon will appear to us when we contemplate it, yet another—a proliferous carnation—is still more remarkable. We see a perfect flower with a calyx and a double corolla; in the centre is a seed-capsule, not, however, quite fully developed. From the sides of the corolla four new and perfect flowers are developed, separated from the parent-flower by stalks three or four nodes or more in length. These new flowers, too, have calyces and double corollas, formed not so much of single petals as of little crowns of petals united at their base, or more often of petals which have developed like little twigs and grown together round a stem. Notwithstanding this monstrous development, filaments and anthers are present in some of these flowers. Fruit capsules are there with their styles, the capsules appearing again in leaf-form. Indeed, in one flower the seed-vessels were united into a perfect calyx and contained the rudiments of another complete, double flower.

106

While the rose was like a half completed flower, from the centre of which the stem again shot upward, bearing stem-leaves as before, the carnation, with a well formed calyx and perfect corolla and a capsule situated properly in the centre, had developed eyes from among the surrounding petals, producing actual twigs and flowers. We see, then, from these two instances, that Nature normally terminates the period of growth in the blossom—adds it up, so to speak, to a sum-total, so that by thus checking the possibility of gradual and infinite growth, she may achieve her aim the more quickly through the forming of seeds.

CHAPTER XVII
LINNAEUS'S THEORY OF ANTICIPATION

107

If here and there I may have stumbled on a path which one of my predecessors, though attempting it under the guidance of his great teacher, describes as so fearful and dangerous; or if I have not quite succeeded in levelling it and clearing it of every obstacle for those who come after me, yet I still hope that this will not have been a fruitless undertaking.

108

At this point it will be right to consider the theory by which Linnaeus sought to explain these phenomena. The things of which this essay treats could not have escaped his keen eye, and if we may now proceed from where he left off, we are indebted to the endeavours of so many observers and thinkers who have dispelled prejudices and cleared away many hindrances from our path. An exact comparison of his theory with one we have just propounded would take too long. Those acquainted with this subject will easily do this for themselves, and such a comparison would be too complicated to be easily intelligible to those who have never thought about these things. We will only point out briefly what hindered Linnaeus from making further progress and reaching the goal.

109

In the first place he made his observation on trees—complicated and long-lived plants. He saw that a tree planted in a fairly large pot and given too much nourishment produced branch after branch for several years, while the same tree, when restricted to a smaller pot, quickly produced flowers and fruit. He saw that the development which before was gradual, then took place all at once. He called this process of Nature "Prolepsis,"—an anticipation—because the plant in the six steps we have been observing, seemed to anticipate six years. He worked his theory out dealing chiefly with the buds of trees without paying particular attention to annual plants, perceiving no doubt that his theory did not fit them so well. For according to his teaching we would have to assume that each annual plant is really intended by Nature to grow for six years, but that in the flower and fruit it suddenly anticipates this space of time, and then fades.

110

We, on the contrary, first studied the growth of annual plants, and now it is easy to apply our deductions to plants of longer duration. For a bursting bud on the oldest tree may be thought of as an annual plant, even though produced from an old stem and capable itself of longer duration.

111

The second cause which held Linnaeus back was that he regarded the circles enclosed one within the other in the stem of the plant—the outer and inner bark, the wood, the pith—too much as being equally active, alive and essential, and to these different circles of the stem attributed the origin of the flower and fruit, because they too seem to encircle and develop from one another. This was, however, only a superficial idea which on closer examination can never be confirmed. The bark is, in fact, unfit for further reproduction and in long-lived trees becomes an obdurate mass on the outside and is separated from the wood within, which has also become quite hard. The bark of many trees falls away and in others it can be taken off without in the least damaging the tree, thus it could not possibly produce either a calyx or any other living part. It is the layer immediately within the bark which has all the power of life and growth, and to the extent that this is injured, the growth of the whole will be disturbed. We shall see too, on closer investigation, that this is the layer which produces all the external parts of the plant—one after the other in the stem, and simultaneously in the flower and fruit. Linnaeus only ascribed to it the subordinate work of producing the petals. To the wood on the other hand, he attributed the all important production of the stamens, although one can clearly see that it is a part which has solidified into a passive condition, durable perhaps, but dead to any stirring of life. And finally the pith was supposed to perform the most important task of all—the production of the feminine organs and subsequently a numerous posterity. The doubts which have been raised as to the great importance of the pith and the reasons for refuting this opinion seem to me weighty and conclusive. It only seemed as though pistil and fruit were developed out of the pith, because these forms, when first we see them, are in a soft undefined state resembling pith or parenchyma, and also because they are pressed together in the centre of the stem where we are accustomed to see the pith.

CHAPTER XVIII
SUMMARY

112

I hope that the present attempt to explain the metamorphosis of plants may contribute something to the solution of these problems and provide occasion for additional comments and opinions. The observations on which my essay is based have already appeared singly and they have also been collected and classified. It will soon be decided whether the step we have just taken is an approach toward the truth. As briefly as possible we shall summarize the chief results of the discussion up to this point.

113

When we consider a plant in relation to its vital force, we see this vitality manifesting itself in two ways : first, through *vegetative* growth, by development of stems and leaves; and next, through *reproduction*, which is completed in the formation of flower and fruit. If we examine the growth phase more closely, we see that the plant, as it vegetates and progresses from node to node, from leaf to leaf, is likewise carrying on a type of reproduction, which differs from that occurring in fruit and flower in that it is *successive* instead of sudden, appearing in a series of individual developments. Yet this vegetative force which exerts itself gradually is very closely related to the force which brings about a marked propagation in one step. Under certain circumstances a plant can be forced to *vegetate* continuously; and on the other hand, its flowering can be *accelerated*. The former situation occurs when there is a considerable influx of cruder saps, and the latter when more rarefied forces are preponderant.

114

By referring to vegetative growth as a successive reproduction, and to the formation of flowers and fruits as a simultaneous one, we have actually characterized the manner of their development also. A plant which vegetates, is expanding more or less: it develops a stalk or stem, the distances from node to node are usually considerable, and its leaves spread out from the stem on all sides. Conversely, a plant which flowers, is contracting all its parts : increments in length and breadth are arrested, and all its organs, developing in close propinquity, are in a highly concentrated state.

115

Whether then the plant vegetates, blossoms, or bears fruit, it nevertheless is always the same organs, with varying functions and with frequent changes in form, that fulfill the dictates of Nature. The same organ which expanded on the stem as a leaf and assumed a highly diverse form, will contract in the calyx, expand in the petal, contract in the reproductive organs, and expand for the last time as fruit.

116

This process of Nature is at the same time bound up with another, with the assembling of *various organs around one central point* in fixed numbers and proportions—greatly exceeded and variously modified, however, in some flowers and under certain conditions.

117

Similarly, anastomosis is in operation during the formation of flowers and fruit, closely uniting the compact and extremely delicate parts of the fructification, throughout their existence or for only part of it.

118

Yet these phenomena of *approach, centralization*, and *anastomosis* are not peculiar to flowers and fructifications alone; indeed we can observe something similar in the cotyledons, and other plant parts will furnish us with abundant material for similar reflections in the sequel.

119

We have ventured to trace back to the leaf form those fruits in which the seeds are firmly enclosed, just as we sought to show that the organs of the vegetating and flowering plant, though seemingly dissimilar, all originate from a single organ, namely, the leaf, which usually develops at each node.

120

It is self-evident that we ought to have a general term with which to designate this diversely metamorphosed organ and with which to compare all manifestations of its form. At present we must be content to train ourselves to bring these manifestations into relationship in opposing directions, backward and forward. For we might equally well say that a stamen is a contracted petal, as that a petal is a stamen in a state of expansion; or that a sepal is a contracted stem leaf approaching a certain stage of refinement, as that a stem leaf is a sepal expanded by the influx of cruder saps.

121

We may likewise say of the stem that it is an expanded flowering and fruiting phase, just as we have predicated of the latter that it is a contracted stem.

122

Moreover, I have at the close of the treatise considered also the development of *eyes* and have thereby attempted to explain compound flowers and unenclosed fruits as well.

123

In this way, then, I have endeavored to set forth, as clearly and completely as I could, a theory which to me has much that is convincing. However, if my theory has not been conclusively demonstrated, if it should still contain contradictions, or if the method of interpretation it employs should not seem at all times applicable : all the more shall I consider it my duty to take note of all criticism and to give the material more exact and extended treatment in the sequel, thereby making this approach to the subject more graphic, and winning for it more universal approbation than can perhaps be expected at present.