ESSAY ON THE METAMORPHOSIS OF PLANTS.

By J. W. von Goethe.—1790.

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[This translation of Goethe's famous Essay is given, because, though the foundation of all that has been subsequently done in vegetable morphology, no complete English translation has ever been published. Dr. Masters's notes are mainly explanatory and confirmatory, and contain references to the writings of Linnæus, Wolff, and others both of Goethe's predecessors and successors in this branch of botanical inquiry.—Ed.]

Introduction.

1. No one who has paid any attention to the growth of plants can have failed to observe that some of their external organs occasionally undergo a change, and assume, sometimes entirely, or in a greater or less degree, the appearance of the organ situated next in order.

2. Thus, for example, a single flower is changed into a double one, petals being developed in the place of stamens, either bearing a perfect resemblance in form and colour to the other petals of the corolla, or still retaining visible signs of their origin.

3. If we reflect that the plant has in this way the power of making an actual retrograde step, and of reversing the order of growth, we shall get more insight into nature's ordinary method of proceeding, and we shall learn to understand those laws of transformation by which she produces one part from another, and exhibits the most different forms by the modification of a single organ.

4. The secret relation subsisting between the different external organs of plants, such as leaves, calyx, corolla, and stamens (which are developed in succession, and, as it were, out of one another), has long been acknowledged by naturalists in a general way; indeed, much attention has been bestowed upon it, and the title Metamorphosis of Plants has been given to the operation by which one and the same organ presents itself to us under various disguises.

5. This metamorphosis is of three kinds,—*regular*, *irregular*, and *accidental*.

6. *Regular* metamorphosis may be equally well styled *progressive;* for it may be observed constantly and gradually at work from the first

seed-leaves to the mature fruit, mounting upwards through a series of transformations, as by an imaginary ladder, to that crowning aim of nature, the propagation of the plant by the male and female organs. I have been attentively observing this process for several years, and it is for the purpose of explaining it that I propose to write this Essay. I shall treat of annual plants only, and the manner in which they progress from the seed to the fruit.

7. *Irregular* metamorphosis might be equally well styled *retrogressive*. For as in the former case nature hastens forward to her great object, she here takes one or more steps backward. In the former instance, with irresistible impulse and powerful effort she forms the flowers and fits them for their office; in the latter she seems, as it were, to relax, and irresolutely leaves her work in an unfinished, weakly condition, pleasing often to the eye, but intrinsically powerless and inactive. By means of practical observations made upon this kind of metamorphosis, we shall unveil that which in the ordinary way of development is concealed from us, and here shall see clearly what there we dare only infer. We may thus hope to attain, with the greatest certainty, the purpose we have in view.

8. We will not take into consideration the third kind of metamorphosis, which is produced *accidentally* and by external causes (especially through the operation of insects),* as it might lead us away from our plain path, and interfere with our object. Occasion may perhaps be found to speak elsewhere of those excrescences, which, monstrous though they be, are nevertheless confined within certain limits.

9. I publish this Essay without illustrations, although in many respects they might appear necessary. I reserve the introduction of them till some future time; an intention which may not improbably be carried out,† as sufficient matter still remains for elucidating and further enlarging the present short and merely prefatory treatise. It will not then be necessary to keep so measured a step as now. I shall be able to introduce much that is illustrative of the subject, and to cite many passages from authors holding similar views. I shall most

* Vid. Dahlberg, Diss. Bot. Metamorph. Plant. sub præsid. Linn. Holm. 1755.

† An edition of Goethe's papers on Natural History was published at Paris in 1837, by Dr. C. F. Martins, accompanied by an atlas containing the author's original drawings, as well as three by Turpin, with notes illustrative of the metamorphosis,—thus carrying out a wish expressed by Goethe in a paper entitled "Wirkung dieser Schrift und weitere Entfaltung der darin vorgetragenen Idee," 1830.

gladly avail myself of any suggestions from those of my contemporaries who are skilled in this noble science, to whom I present and dedicate these pages.

I. *Of the Seed-leaves.*

10. Having undertaken to observe the successive steps in the growth of a plant, let us first direct our attention to it when it begins to germinate. We can, at this stage, easily and exactly distinguish its component parts. Its coverings (which we will not now stay to examine) remain more or less concealed in the soil, and (in many instances) the root is established before the plant exhibits those first organs of its upward growth, which were previously hidden in the seed.

11. These organs are called cotyledons, and also seed-lobes, seed-leaves, etc., from their different forms.

12. They are often unshapely, charged as it were with a crude substance, and very thick in proportion to their breadth; their vessels are not recognizable, being scarcely distinguishable from the general mass; they have, moreover, very little resemblance to leaves, and we are in danger of being led to regard them erroneously as distinct organs.

13. Yet in many plants they nearly approach the form of a leaf; they become flatter, and, on being exposed to light and air, they assume a deeper green; the vessels become recognizable and more like the veins of a leaf.*

14. At length they assume the appearance of true leaves, the vessels are perfectly developed, and their similarity to the leaves, subsequently produced, show that they are not distinct organs, but simply the first leaves of the stem.†

15. Now, as we cannot realize the idea of a leaf apart from the node out of which it springs, nor of a node without a bud, we may venture to infer 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

* The consistence and size of the cotyledons are very generally in inverse relation with the amount of the perisperm or albumen; where this is abundant, the cotyledons are small, or thin and leaf-like, and possess nervures, stomata, etc., like other leaves, and as they are exposed to light and air, they perform the same functions as ordinary leaves do; while the thick fleshy cotyledons remain below the surface of the soil, and seem to serve the purpose of storehouses, whence the young plant may derive nutriment.

† Foliaceous cotyledons may be well seen in the seeds of the Lime, Sycamore, *Ricinus*, etc.

emit buds from the axils of their cotyledons, and develope perfect branches from these first nodes, as the common Bean (*Vicia Faba*).

16. The cotyledons are generally two in number, and here we make a remark, the importance of which will appear more by-and-by. The leaves of this first node often appear *in pairs*, whilst the subsequent leaves of the stem are placed *alternately;* an approximation and connection being thus shown between parts which nature subsequently separates and places at a distance. The case is still more remarkable when the cotyledons appear like a number of little leaves round a common axis, whilst upon the stem, which rises from the centre, the subsequent leaves are developed singly; this may be osberved in the different kinds of Pine, the cotyledons of which are a crown of needle-shaped leaves. As we proceed we shall meet with similar phenomena.*

17. We shall not consider, at present, the plants which have only a single cotyledonary leaf.

18. Let us, however, pause to remark that even those cotyledons which most resemble leaves, when compared with the subsequent stem-leaves, are always imperfectly formed. Their margin is entire, with as few traces of incisions in it as of hairs on the surface, or any of those vessels which are to be observed in perfect leaves.†

II. *On the Formation of the Stem-leaves at the successive Nodes of the Stem.*

19. We are now able to observe with accuracy the successive formation of the leaves, as now the progressive operations of nature all take place before our eyes. Some, or many, of the leaves which now appear, often exist previously in the seed, enclosed between the cotyledons, and are then called the plumule. Their shape, relatively to that of the cotyledons and of the future leaves, varies in different plants; but they

* Duchartre says that the appearance of several cotyledons in the Pines and some other plants, is due to the subdivision of each of the two cotyledons into a number of lobes. (Ann. des Sc. Nat. 3rd ser. vol. x. p. 234.) Whether the four cotyledons of *Nuytschia*, an Australian terrestrial Loranthacea, are due to a similar sub-division, is not stated.

† Occasionally, however, the cotyledons are lobed or notched at their margins, as in the Geranium, while at other times they possess hairs on their surface, as in *Gossypium*, or little vesicular glands, as in Myrtles, etc. These instances do but afford further proofs of the identity between the cotyledons and the leaves. For a full account of the homologies of these organs, see De Candolle, 'Organographie Végétale,' vol. ii. p. 97.

differ most from the cotyledons in being flat and of a delicate texture, and especially in being formed like true leaves, in being perfectly green, and in being situated on a visible node. Their connection with the future stem-leaves can no longer be denied; they are nevertheless inferior to them in the imperfect state of their margin.

20. At each successive node the form of the leaf attains greater perfection; the midrib lengthens, and the side-ribs, which arise from it, extend more or less towards the margin. The different relations of the ribs to each other are the principal cause of the various shapes we observe in leaves,* which are notched, deeply incised, or formed of many leaflets, looking like little branches. The Date Palm is a striking instance of the most simple form of leaf becoming gradually but deeply divided. As the leaves succeed each other, the midrib lengthens, till at last it tears asunder the numerous compartments of the simple leaf, and an extremely compound, branch-like leaf is formed.†

21. The development of the leaf-stalk keeps pace with that of the leaf; the stalk being either closely coherent with the leaf, or so formed as ultimately to be easily severed from it.

22. We see in different kinds of plants that this independent leaf-stalk has a tendency to assume the form of a leaf, as in the Orange; its structure, which for the present we pass over, will afford us matter for future consideration.‡

23. Neither can we now enter upon a closer examination of the stipules; we can only remark in passing that, especially in those instances where they constitute a part of the leaf-stalk,§ they share its future transformations in a remarkable manner.

24. Whilst the leaves principally derive their first nourishment from the more or less modified fluids which they draw from the stem, it is to

* Schleiden, Trécul, and most modern observers hold that the mode of distribution of the ribs of the leaf depends essentially on the form of the latter. De Candolle, however, was of the opposite opinion.

† Trécul describes the leaf of the Date Palm as a compound leaf, the pinnules of which are attached by their points to a cellulo-fibrous cord, which surrounds the whole leaf. By the rupture of this cord, and by the peeling off, in thin scales, of a brownish pellicle, which at first covers the whole surface of the leaf, the pinnules become at length separated from each other. (Trécul, Mém. sur la Formation des Feuilles, Ann. des Sc. Nat. 3rd ser. vol. xx. p. 285.)

‡ As illustrations may be cited the phyllodia, or dilated foliaceous petioles of some species of *Acacia*, *Oxalis*, etc.

§ For a concise account of the different kinds of stipules, see Griffith, Notulæ, vol. i. p. 233.

the light and air that they are indebted for their increased perfection in form, and for the delicacy of their tissue. The cotyledons which are produced beneath the covering of the seed, are charged as it were with nothing but a crude kind of sap, are scarcely at all, or but rudely organized and undefined; in the same way the leaves of plants which grow under water are more rudely organized than others which are exposed to the air; nay, even the same kind of plant will develope smoother and more imperfectly formed leaves when growing in low, damp situations, than it will if transplanted to a higher region, where, on the contrary, the leaves will be rough, hairy, and more delicately finished.

25. So also the anastomosis of the vessels which arise from the ribs, and continually tend to inosculate at their extremities (by which also the cuticle (*Blatthäutchen*) of the leaf is formed), is, if not entirely produced by subtile gases, at least greatly accelerated by them.* The reason why the leaves of many plants which grow under water are capillaceous, is owing to an imperfect anastomosis. This is clearly shown in *Ranunculus aquatilis*, where the aquatic leaves consist of capillaceous veins, whilst in the aerial leaves the anastomosis is complete, and a connected surface is formed.†

26. Experiments have shown that leaves absorb different kinds of gases, and combine them with their sap; these juices are returned in a more refined state into the stem, and thereby eminently promote the formation of the adjacent buds. Gases disengaged from the leaves and hollow stems of different plants have been analysed, and afford the most convincing evidence of this.‡

27. We observe in many plants that one node arises from another. In the jointed stems of the cereals, grasses and reeds, this is obvious; but it is not so obvious in plants whose centre is either hollow through-

* What share subtile gases can have in the formation of the cuticle, and in the inosculation of the veins, is by no means obvious.

† The filamentous condition of the leaves of some water-plants is rather due to the scanty development of the cellular portions of the leaf (*parenchyma*) than to the imperfect inosculation of the fibro-vascular bundles. The leaf of the Lattice-plant of Madagascar, *Ouvirandra fenestralis*, affords a remarkable illustration of the deficiency of parenchyma; here the inosculation of the veins is perfect, but as the spaces between them are not filled up with cellular tissue, the whole leaf has the appearance of lace-work; it may also not inaptly be compared with the so-called skeleton leaves produced by maceration.

‡ The most important recent memoir on this subject is that of Boussingault, in Ann. Sc. Nat. 1862.

out or filled with pith or cellular tissue. The supposed important functions of the pith having been on good ground called in question, and the impulsive and productive power once attributed to it being now unhesitatingly given to the inner side of the second bark (the so-called pulp),* we can more easily understand that whilst an upper node arises from the previous one, and receives the sap by means of it (receives it, too, in a more elaborated condition from the intervening operation of the leaves), it must not only attain to a more perfect state itself, but must consequently transmit a more elaborated sap to its own leaves and buds.

28. Whilst, therefore, the less pure fluids are got rid of, purer ones are introduced, and the plant having been gradually brought into a more perfect condition, attains the end prescribed to it by nature. We see the leaves at length perfectly developed in size and form, and soon become aware of a fresh phenomenon, which tells us that the period we have been observing has reached its termination, and that a new one is approaching, that, namely, of the *Blossom*.

III. *Transition to the Flowering-period.*

29. The transition to the period at which the flower appears, takes place with greater or less rapidity. In the latter case the stem-leaves generally become gradually smaller and less divided, whilst increasing more or less in width at their base; at the same time the space between the nodes of the stem, if not perceptibly lengthened, becomes at least more slender and more delicately formed.

30. It has been observed that if a plant is supplied with copious nourishment, the flowering-period is delayed, but that moderate or even scanty nourishment accelerates it.† The functions of the stem-leaves is thus clearly shown. As long as there are crude juices to be carried off, the plant must be provided with organs competent to effect the task. If superfluous nourishment is forced on the plant, the operation must be continued, and flowering becomes almost impossible. But, on the other hand, if nourishment is withheld, that operation of nature is facilitated and hastened; the organs of the nodes (leaves) be-

* The formative tissue between the wood and the bark of an exogenous tree is now called cambium :—there is growth most active, manifesting itself in the formation of wood on the one side, of bark on the other; therein are the channels by which the elaborated sap mostly passes in its descent.

† Wolff, 'Theoria Generationis,' 1759; Linn. Prolepsis, §§ iii. and x.

come more refined in texture, the action of the purified juices becomes stronger, and the transformation of parts having now become possible, takes place without delay.

IV. *On the Formation of the Calyx.*

31. This transformation often takes place *rapidly;* the stem at once becomes tapering and delicately-formed, and shoots upwards from the node at which the last perfect leaf was developed, terminating in a whorl of leaves collected round an axis.

32. It appears to us a fact capable of the clearest proof, that the leaves of the calyx are the same organs as those whose formation we have hitherto been observing as stem-leaves, though now often in a very altered condition, and collected round a common centre.

33. We have already observed in the cotyledons a similar operation, and have seen a number of leaves, and thus obviously a number of approximated nodes, collected round a central point. The cotyledons of the Pine are a rayed circle of needle-shaped leaves with a definite form; even in the earliest infancy of those plants that vigour of constitution is, as it were, indicated, by which, at a more advanced age, the blossoms and fruit are to be produced.*

34. We further see, in many flowers, unaltered stem-leaves collected together so as to form a kind of calyx immediately below the inflorescence. That they are stem-leaves we need only appeal to the normal appearance still retained, and to botanical terminology, which designates them by the name of *Folia floralia* (bracts).

35. We must now observe the case in which the transition to the flowering-period proceeds *slowly;* the stem-leaves gradually diminish in size, become altered in appearance, and gently insinuate themselves into the calyx, as may be very easily seen in the common calyx (*involucrum*) of Composite flowers; especially in Sunflowers and Marigolds.†

* The force of the argument in this paragraph is destroyed by the researches of Duchartre; see *ante*, note to § 16.

† The nature of the involucre was pointed out by Jung. 'Isagoge Phytoscopica,' 1678, cap. xiv. §§ 14, 15, 23.

Similar instances of the close similarity that exists between the leaves and the bracts constituting an involucre may be seen in many Umbelliferous plants, as the Carrot, in the Anemone, etc. A remarkable instance is figured in the 'Gardeners' Chronicle,' Sept. 11, 1852, of a Dahlia, in which the bracts or scales of the involucre and the paleæ (scales) of the receptacle, instead of retaining their usual membranous state, have all assumed the texture, colour, and veins of leaves, even narrowing their bases into footstalks. So we have seen the bracts of the Plantain, *Plantago major*,

36. Nature's power of collecting a number of leaves round a common axis is seen to produce even a closer union, so as to render these clustered and modified leaves still more difficult to recognize; that is to say, it unites the edges of one with the other, often entirely, but frequently only in part. The crowded and closely-pressed leaves are brought into the nearest contact with each other while yet in a tender state, an anastomosis is effected by the operation of the elaborated juices which the plant now contains, and they thus form a bell-shaped or so-called *monosepalous calyx*, which betrays its compound origin by the manner in which its border is more or less incised or divided. We may find evidence of this by comparing a number of deeply-divided calyces with polysepalous ones, especially if we attentively consider the common calyces (involucres) of many Composite flowers. Thus, we shall find that the calyx of a Marigold, which is defined in systematic descriptions as *simple* and *much divided*, consists both of attached and imbricated leaves, amongst which, as we said above, diminished stem-leaves have, as it were, insinuated themselves.

37. In many plants the number and form in which the calyx-leaves (sepals), whether distinct or united, are arranged round the axis of the stalk, is constant, the same regularity being observable in the other subsequent organs. On this constancy of character depend, in great part, the progress, stability, and reputation of botanical science, which of late years has been making continual advances. There are, indeed, instances in which the number and form of these parts are not equally constant; yet even this inconstancy has not baffled the keen powers of observation which distinguish the masters of this science; they have endeavoured, by means of exact definitions, to impose a strict limit, so to speak, within which these aberrations of nature are restrained.*

38. Nature has thus formed the calyx by *uniting together*, around a common centre, generally in a certain definite number and order, many leaves, and consequently many nodes, which she had previously produced *in succession, and at some distance from each other*. Should, however, the flowering-period have been checked by an excessive and

presenting in all respects the form and size of the ordinary leaves, and we have observed similar changes in the scales of the strobile of the Hop, and in those of the Larch, *Cryptomeria*, etc. In *Podolepis* the bracts are stalked like ordinary leaves. (Vid. Moquin-Tandon, 'Tératologie Végétale,' p. 202.)

* "Calyx tunc plane non differt a foliis proxime ipsi præcedentibus." (Wolff, 'Theoria Generationis,' 1759, § 114.)

superfluous degree of nourishment, they would have remained separate from each other, and would still have retained their original form. Nature, therefore, forms no new organ in the calyx, but simply unites and modifies those organs with which we are already acquainted, and advances by this means a step nearer her object.*

V. *On the Formation of the Corolla.*

39. We have seen how the calyx is produced by highly-elaborated fluids, gradually generated in the plant; and in the same way the calyx itself is destined to become the organ of a future and further degree of elaboration. This will appear easy of belief if we take into consideration the purely mechanical nature of its operation. The state of contraction and compression in which its vessels are now found, as shown above, renders them of an extremely delicate nature, and thus well adapts them for the process of a most elaborate filtration.

40. The transition of the calyx into the corolla is exhibited in various ways; for although the general colour of the calyx usually remains green, like that of the stem-leaves, it often shows a change in one part or another, at the tips, the edges, or at the back, or over the whole of the inner surface, while the outer surface remains green; and whenever this change of colour occurs, we see it combined with an increased refinement of texture. In this manner an ambiguous kind of calyx is produced, which might with equal propriety be called a corolla (perianth of Linnæus).†

* Wolff, Nov. Comm. Acad. Petrop. pp. 403, 1766, 1767; Linn. Prolepsis, § 6. The resemblance of sepals to leaves is well shown in *Agrostemma Githago*, some kinds of Rose, of Pæony, of Gentian, of *Mesembryanthemum*, etc., while in the Camellia, and a great number of other plants, the sepals are not arranged in a verticillate manner, but are disposed in a spirally imbricated arrangement, as is commonly the case with ordinary leaves. On the other hand, the whorled leaves of all the *Stellatæ*, etc., may be adduced to show the similarity between such an arrangement, and that which usually obtains in the calyx. Floral leaves or bracts are frequently only to be distinguished from ordinary leaves by their position at the base of the flower; at other times the bracts gradually assume more and more of the appearance of the sepals, as in *Calycanthus*, *Berberis*, *Cactus*, and others, in which no definite line can be drawn between sepals and bracts. In *Peganum* and *Cruckshanksia*, the sepals are even provided with stipules. Few plants show the gradual passage of leaves to bracts and sepals so well as *Helleborus fœtidus*.

† Linn. Prolepsis, § 8. The sepals of the white Water Lily, *Nymphæa alba*, are of an olive-green colour on the outside, and of a white or pinkish hue on the inner side. The tips of the sepals in the *Helleborus fœtidus* are of a purple colour, and other Ranunculaceæ furnish instances of coloured calyces in the Winter Aconite, Larkspur, Aconite, Columbine, Anemone, etc. The Fuchsia is a well-known instance of the same thing.

41. We remarked that from the seed-leaves upwards a great development takes place both in the size and form of the leaves, especially in their margins, and that a subsequent diminution of their size occurs in the calyx; we have now to observe a second act of expansion, by which the corolla is produced. The flower-leaves (petals) are usually larger than the calyx-leaves (sepals), and it is to be remarked that as a contraction of the organs occurs in the calyx, so (having been in a high degree refined by means of a further filtration of the fluids in passing through the calyx) they again expand in the form of petals, and assume the appearance of entirely new and distinct organs. Their delicate organization, their colour, and their scent would make it impossible to recognize their origin, if we had not frequent opportunities of stealthily observing nature when departing from her general rule.

42. Thus, for instance, within the calyx (epicalyx) of a Pink a second calyx is often found, which, being partly green, was to all appearance originally designed for a monosepalous notched calyx, but its jagged tips, and edges transformed into incipient and spreading petals, betray, both by their colour and texture, the relationship that exists between the corolla and the calyx.

43. The relationship of the corolla to the stem-leaves is also shown in different ways; for stem-leaves already more or less coloured may be seen on many plants, far below the inflorescence, those nearest to it being coloured throughout.*

44. Those instances also in which nature, as it were, altogether omits the calyx,† afford additional opportunities of observing the transformation of the stem-leaves into petals. On the stalks of tulips, for example, a coloured petal, almost perfect in form, may often be seen. The case is even more remarkable when a leaf, half green and half coloured, remains attached to the stem by the green part as more properly belonging to it, whilst the coloured portion is carried up with the corolla, so that the leaf is literally torn asunder.‡

* The brightly coloured bracts in some of the species of *Salvia*, *Euphorbia*, *Poinsettia*, etc., afford good illustrations of the facts mentioned in this paragraph. We have also seen several instances where the involucre of the garden Anemone had assumed as brilliant a crimson colour as the calyx itself.

† Where but one whorl exists on the outside of the stamens or pistils, that one is called a calyx, irrespective of its colour. The term 'perianth' is applied in some cases where it is difficult to distinguish the calyx from the corolla.

‡ Prolepsis, § 7. Instances of the substitution of ordinary leaves for petals in Roses, in Clover, and other plants, are not uncommon. We have seen such in *Petunias*, *Lychnis*, etc. See Moquin-Tandon, 'Tératologie Végétale,' pp. 203–7 and 230.

45. There is great probability in the opinion that the colour and scent of the petals is to be ascribed to the presence of pollen within them; it probably exists in them in an imperfectly disengaged state, or rather combined with and diluted by other fluids. The very beauty of the colours induces the idea that the substance contained in the petals, though in an extremely purified condition, has not yet attained the very highest degree of purity, at which stage it appears white and colourless.*

VI. *On the Formation of the Stamens.*

46. The opinion alluded to in the last paragraph will appear still more probable, when we consider the close connection which exists between the petals and the stamens. If the connection between all the other organs were as obvious, as universally noticed, and considered as indubitable, the present essay might be thought superfluous.

47. Some plants normally produce their petals in a transitional state; as *Canna*, and other plants of the same family. In this instance a true petal, but slightly changed, is contracted at the upper part, and exhibits an anther, in relation to which the rest of the petal stands in the place of the filament.†

48. In those flowers whose habit it is to become double, we may trace this transition through all its different stages. In Roses, among perfect coloured petals, others may often be seen which are contracted both in the middle and at the side. This is occasioned by a little protuberance more or less resembling a perfect anther, and in the same proportion the whole petal assumes the form of a stamen. In the case of many double Poppies, some of the petals of the very double corolla

* In accidental cases, where the petals assume more or less the appearance of stamens, or *vice versâ*, the pollen may be said to be in the petal; and in the common Mistletoe the inner surface of the flower has numerous small depressions in which the pollen is lodged, but it seems little better than a fancy to attribute the colour and scent of the petals of an ordinary flower to the pollen contained within them. The true cause of these phenomena is very imperfectly known; coloured liquids in the cells of the petals are in many cases the source of the colour, and volatile oils contribute in some cases to their odour, but for the most part we are ignorant of the cause of the exquisite perfume of some plants.

† The flowers of *Canna* have three sepals, an irregular corolla in five or six divisions; the whole of the stamens are replaced by petals, with the exception of one half-anther placed on the side of a petaloid filament. The style, which in the adult state is simple and flattened like a petal, offers in its earliest condition three small divisions, corresponding to the three carpels of the ovary. (See Barnéoud, Ann. des Sc. Nat. 3rd ser. Bot. viii. p. 344.)

are little changed, and tipped with perfectly developed anthers; whilst others are more or less contracted by anther-like protuberances.*

49. When all the stamens are changed into petals, the flower produces no seed, but if any of the stamens are developed whilst the process by which the flower becomes double is going forward, fertilization may take place.

50. A stamen, then, is produced by the re-appearance of the selfsame organ diminished and refined, which we just before saw expanded as a petal. The truth of the proposition put forward above is hereby again confirmed, and our attention becomes still more closely riveted on this operation of alternate contraction and expansion, by means of which nature at length attains her object.†

VII. *Of the Nectaries.*

51. However rapidly the transition takes place in many plants from the corolla to the stamens, we nevertheless perceive that nature cannot always effect it in a single stride; that is to say, she produces intermediate organs which, in their form and office, at one time resemble the petals, and at another the stamens. Though varying extremely in form, they may nevertheless be almost all comprehended under one idea, namely, that *there may be slow stages of transition between the petals and the stamens.*

52. Most of these differently-formed organs, which Linnæus called nectaries, may be thus defined; and here we have fresh reason to admire the great penetration shown by that extraordinary man, who without clearly comprehending their office, yet ventured, in reliance upon a surmise, to include apparently different organs under one and the same name.

* The transition from petals to stamens may be well seen in the common white Water Lily, in some species of *Atragene*, etc. In *Bocagea viridis* there is no difference in form between the stamens and the petals. Double flowers result from the substitution of petals for stamens or pistils, and from other causes. See De Candolle, Mém. sur les Fleurs Doubles, Mém. Soc. Arc. t. iii. p. 402, and Moquin-Tandon, 'Tératologie Végétale,' p. 211.

† Wolff's original opinion was that the stamens were equivalent to so many buds placed in the axil of the petals or sepals (see 'Theoria Generationis,' 1759, § 114)—an opinion which more recently has received the support of Agardh and Endlicher. Wolff himself, however, seems to have abandoned his original notion, for in his memoir, "De formatione intestinorum præcipue tum et de amnio spurio aliisque partibus embryonis Gallinacei, nondum visis," etc., in Comm. Acad. Petrop. xii. p. 403, anno 1766, he considers the stamens as essentially leaves. See also, Linn. Prolepsis, § viii.

53. Many petals, without being perceptibly altered in form, nevertheless indicate their relation to the stamens by having little cavities, or by glands attached to them, from which a honey-like liquid exudes. That this may possibly be the fructifying mixture in a yet imperfect, unelaborated state, we may partly conjecture on the grounds above alleged, and this will appear still more probable from reasons to be presently adduced.*

54. In other instances the so-called nectaries assume the appearance of independent organs, and under this disguise they sometimes mimic the petals, sometimes the stamens. Take as examples the nectaries of *Parnassia*, in which thirteen filaments, each tipped with a little red ball, bear a strong resemblance to stamens; or *Vallisneria* and *Feuillæa*, where they are like filaments without anthers; or *Pentapetes*, in which they have a leaf-like form, and are arranged in a circle alternating regularly with the stamens. In systematic works these organs are described as *filamenta castrata petaliformia*. Similar ambiguous formations occur in *Kiggellaria* and the Passion-flower.

55. The name of nectary, as explained above, may be equally well applied to the peculiar *accessory corolla* ('paracorolla,' Schleiden). If the formation of the petals is produced by expansion, the accessory corolla is the result of contraction, as in the case of the stamens. Thus we sometimes see within a perfect and wide-spreading corolla, a smaller and contracted accessory one, as in *Narcissus*, *Nerium*, and *Agrostemma*.†

* At the base of the petals of the Crown Imperial, *Fritillaria imperialis*, there exists such a gland as that mentioned in the text.

† The crown of the *Narcissus* has been the subject of much discussion among botanists, and its real nature can hardly be said to be yet satisfactorily made out. M. Gay (in Bull. Soc. Bot. France, vi. 1859) gives a concise account of the opinions of previous observers. His own opinion seems to be nearly the same as that of Schleiden, and that the organ in question is formed from the confluence of six intra-perianthial stipules ('ligules,' Schleiden). Our own observations, so far as they go, lead us to support Dr. Lindley's views that the corona of *Narcissus* is composed of a row of antherless stamens, whose filaments are petaloid and coherent. M. Gay's objections to this view do not appear to us valid, while, on the other hand, Dr. Lindley's opinion is supported by the analogy of *Pancratium*. Moreover, in *N. incomparabilis* the corona is somewhat six-lobed, the lobes alternating with the segments of the perianth on the one side and with the stamens on the other; again, the divisions of the cup which are placed opposite to the outer segments of the perianth overlap the remaining ones, which oppose the inner pieces of the perianth,—an arrangement recalling the similar disposition of the stamens in the common *Polyanthus Narcissus*. In *N. montanus* we have seen, for several years in succession, anthers placed on the corona, and the latter sometimes divided into segments, not differin-

56. Still more striking and remarkable alterations are produced in the petals of different plants. A small cavity, filled with a honey-like liquid, occurs in the inner base of some flowers. This cavity is much deeper in some families and species than in others, and is elongated at the back of the petal in the shape of a spur or horn, the rest of the petal being also more or less modified in form. The genus *Aquilegia* is a good example of this.*

57. The nectary is most disguised in *Aconitum* and *Nigella*, but even here its similarity to the 'leaf-form' may be perceived by a little attention; it has a strong tendency in *Nigella* to become petaloid, the flower becoming double from the altered nectaries. In *Aconitum* the resemblance of the nectaries to the helmet-shaped sepal, beneath which they are concealed, is evident.†

58. Having observed above that the nectaries may be considered as transitional organs between petals and stamens, we may here introduce a few remarks on irregular flowers. In *Melianthus* the five outer divisions may be described as true petals, and the five inner ones as an accessory corolla consisting of six nectaries, of which the superior one is most like the petals, whilst the inferior one, commonly called the nectary, most differs from them. In the same sense the keel of papilionaceous flowers‡ might be called a nectary, since of all the petals it is nearest in form to the stamens, whilst it differs widely from the leaf-like form of the standard (vexillum). Thus also the brush-like

from the ordinary stamens except in the breadth of the filament. Anthers so placed are commonly met with in some of the double *Narcissi*.

Schleiden also asserts that the nectaries of *Ranunculus* and *Parnassia*, the scales of *Sileneæ*, and the crown of the Passion-flower, are secondary productions from the petals, and not independent foliar organs; but, on the other hand, some of the rays of the crown of the Passion-flower have been observed to be replaced by anthers (Moquin-Tandon, 'Tératologie Végétale,' p. 220), while in *Passiflora Murucuja* the rays are combined into a cup, like that of *Narcissus* or like that of *Melia*, except that it does not bear anthers. In *Saponaria* and some others of the *Sileneæ* we have remarked the scales of the corona bearing anthers as though they were referable to the adhesion of two stamens, the anthers of which are usually wanting (Journ. Linn. Soc. i. 1857, p. 159).

* In *Angræcum sesquipedale*, an Orchid native of Madagascar, the nectary measures nearly a foot in length.

† The parts called by Goethe nectaries, in the Aconite, Nigella, etc., are now considered as petals, the outer pieces as sepals, in spite of their colour and form. In the Winter Aconite, *Eranthis hyemalis*, a transition may sometimes be seen between the large, flat, coloured sepals and the small, tubular, greenish petals (nectaries).

‡ The keel in papilionaceous flowers is evidently formed by the junction of two petals.

appendages attached to the end of the keel, in some species of *Polygala*, may be explained, and a distinct idea formed as to what these organs really are.

59. It would be superfluous to assert that it is not the object of these remarks to re-entangle what has been separated and classified by the labours of observers and systematists; the intention is simply to render the different forms of plants more susceptible of explanation by means of the views here put forward.

VIII. *A few more Remarks on the Stamens.*

60. It has been placed beyond all doubt, by microscopic observations, that the stamens and pistils, no less than the other organs of plants, are produced by spiral vessels. We found an argument upon this as to the intrinsic identity of the various parts of plants, however different the forms under which they appear.*

61. Now the spiral vessels being situated in the very centre of the bundles of sap-vessels, and entirely surrounded by them, we shall be able to form a truer estimate of their strong contractile power, if we imagine them (as, indeed, they have all the appearance of elastic springs) in the very act of exerting their utmost force, till having gained the mastery, they altogether overcome the expansive power of the sap-vessels.

62. The ramification of the bundles of sap-vessels is now rendered impossible, nor can they any longer unite and form a network by anastomosis; the (cellular tissue) which generally fills up the interstices of the network is no longer developed; all the causes which produced the expansion of the stem-leaves, the sepals, and the petals, are at an end, and an extremely simple little filament makes its appearance.

63. No sooner are the delicate membranes of the anther formed, than the extremely attenuated sap-vessels terminate in them. And now, if it be admitted that these are the very same vessels in a state of extreme contraction as those which before were continually increasing in length, ramifying and uniting with each other; if at this stage, moreover, we see highly organized pollen developed from them,† which

* It can hardly be correctly said that the stamens and other organs of plants are produced by spiral vessels, since all these parts begin as little knobs or pimples of fine cellular tissue, and spiral vessels are not formed therein till after development has proceeded some way.

† The mode of explaining the formation of the pollen is now known to be incorrect.

compensates by its energy for what those vessels have lost in power of expansion; if, when this pollen is set free, it immediately seeks the pistils (placed by nature in close proximity with the stamens), if it attaches itself to the pistils, and imparts its influence to them,—then are we by no means averse to consider the union of the male and female organs as an ideal anastomosis,* and we think that, for the moment at least, we have brought the ideas of growth and reproduction a step nearer to each other.

64. The subtile substance which is organized in the anthers looks like mere powder, but the little pollen-grains are in fact nothing more or less than vessels (cells) in which an extremely refined moisture is enclosed. We coincide, then, in the opinion of those who maintain that this moisture is absorbed by the pistils to which the pollen-grains attach themselves, and that thus the fructification is effected. This appears the more probable, from the fact that some plants secrete no pollen-grains, but moisture only.†

65. We are here reminded of the honey-like liquid of the nectaries, and its probable connection with the elaborated moisture contained in the pollen-grains. Perhaps the nectaries are preparatory organs, and their honey-like moisture may possibly be absorbed, perfected, and fully elaborated by the anthers; an opinion which derives greater probability from the disappearance of this fluid after fructification has taken place.‡

66. We must not omit a cursory remark as to the different ways in which the filaments unite with each other in some flowers (Monadelphia, etc.), and the anthers in others (Syngenesia), exhibiting the most curious examples of anastomosis and combination between organs which at an earlier stage were perfectly distinct.

* The discovery of the pollen-tubes has rendered this far more certain than it was at the time when Goethe wrote.

† It is needless to do more than remark that modern research has completely shown the falsity of the opinion stated in this paragraph.

‡ Vaucher (Hist. Phys. Pl. Europ. p. 13) held that the honey-like liquid of flowers plays a very important part in the fertiiization of the ovule, especially by dissolving the pollen and fitting it for its office. He pointed out the existence of nectaries or secreting organs in many flowers where they had not previously been detected. See also Brongniart, 'Sur les Glandes Septales de l'Ovaire,' Ann. Sc. Nat. 4th ser. ii. p. 1. Darwin ('On the Various Contrivances by which British and Foreign Orchids are Fertilized by Insects,' 1862, p. 278, etc.) shows that the nectar is of the highest importance to Orchids, by attracting insects, without whose agency fertilization could not be effected.

IX. *On the Formation of the Style.*

67. If thus far our object has been to show that the different organs of plants, developed in succession, are intrinsically identical, however unlike externally, it will be easily conjectured that our next aim will be to explain the structure of the pistil on the same principle.

68. We will first consider the style as independent of the fruit, as indeed we often find it in nature, and the fact of its being thus distinct will make our task the easier.

69. The style then, we observe, is to be referred to the same period of growth as the stamens; the stamens, that is to say, are the result of contraction, and the same thing may be often asserted of the styles; if, indeed, their proportions do not always keep pace with those of the stamens, the difference in their length is but slight. In many instances the style has almost the appearance of a filament without an anther, and they are more nearly allied in external form than any of the other organs. Since both are produced by spiral vessels,* it becomes so much the more evident that neither pistils nor stamens are distinct organs, and if by this consideration their close relationship is rendered obvious, it appears to us that the idea of an anastomosis, as applied to their union, is both appropriate and intelligible.

70. We often find that the style is composed of many single styles united; the parts which compose it are scarcely discernible even at the tip, nor even there are they always separated. Such adhesion (upon the effect of which we have already often remarked) may easily take place in this instance, indeed it must inevitably occur, because these delicate organs, before the time of their perfect development arrives, are pressed together in the centre of the flower-bud, and may there effect the very closest union.

71. There are many instances of a constant kind in which nature shows us more or less clearly the connection of the style with the preceding organs of the flower. The style of the *Iris* and its stigmas, for example, are obviously petaloid. The shield-shaped stigma of the *Sarracenia* betrays, though less obviously, that it is composed of several leaves, and even the green colour is retained. If we call in the aid of the microscope, we find many stigmas, as for example those of the *Crocus* and the *Zannichellia*, formed like perfect mono- or polysepalous calyces.

* See note to § 60.

72. Nature not unfrequently affords us instances in which, by a retrogressive movement, the style and stigmas are reconverted into petals. It is, for example, by such a transformation that *Ranunculus Asiaticus* becomes double, the anthers being often found unchanged immediately beneath the corolla. Some other remarkable instances will be mentioned by-and-by.*

73. We must here repeat the observations before asserted, that the style and stamens are to be referred to the same period of growth, and that they hereby afford a fresh illustration of the argument by which we endeavoured to prove a process of alternate expansion and contraction. From the seed to the topmost stem-leaf we observed the work of expansion going forward; we next saw the calyx produced by means of contraction, the petals by expansion, and again the stamens and pistils by contraction. Presently we shall have to observe the highest degree of expansion in the fruit, and the utmost concentration in the seed. In these six steps unwearied nature completes her never-ending work of reproduction, by means of the male and female organs.†

INFLAMMABILITY OF THE FLOWERS OF *DICTAMNUS ALBUS.*

When the daughter of Linnæus one evening approached the flowers of *Dictamnus albus* with a light, a little flame was kindled without in any way injuring them. The experiment was afterwards frequently repeated, but it never succeeded; and whilst some scientific men regarded the whole as a faulty observation or simply a delusion, others endeavoured to explain it by various hypotheses. One of them especially which tried to account for the phenomenon by assuming that the plant developed hydrogen, found much favour. At present, when this hypothesis has become untenable, the inflammability of the plant is mentioned more as a *curiosum*, and accounted for by the presence of etheric oil in the flowers. Being in the habit of visiting a garden in

* Linn., Prolepsis, § ix., mentions some flowers of *Carduus heterophyllus* and *C. talaricus* in which "the style had grown into two green leaflets, the calyx and corolla were also leaf-like in these flowers."

† See Braun, 'Rejuvenescence,' Henfrey's translation for Ray Society, 1853, p. 60.

in the Ingleborough district, and that its Continental distribution is not opposed to its being found with us; but it is desirable to have modern confirmation of its occurrence before it can be with certainty called a British plant.

As *H. alpina* is described by Reichenbach, Koch, Godron, Boreau, and others, it is only necessary to add that its unbranched stem and large petals clearly distinguish it from *H. petræa*, which it does not resemble even in aspect.

ESSAY ON THE METAMORPHOSIS OF PLANTS.

By J. W. von Goethe.—1790.

Translated by Emily M. Cox; *with Explanatory Notes by* Maxwell T. Masters, M.D., F.L.S.

(*Concluded from p.* 345.)

(Plate XI.)

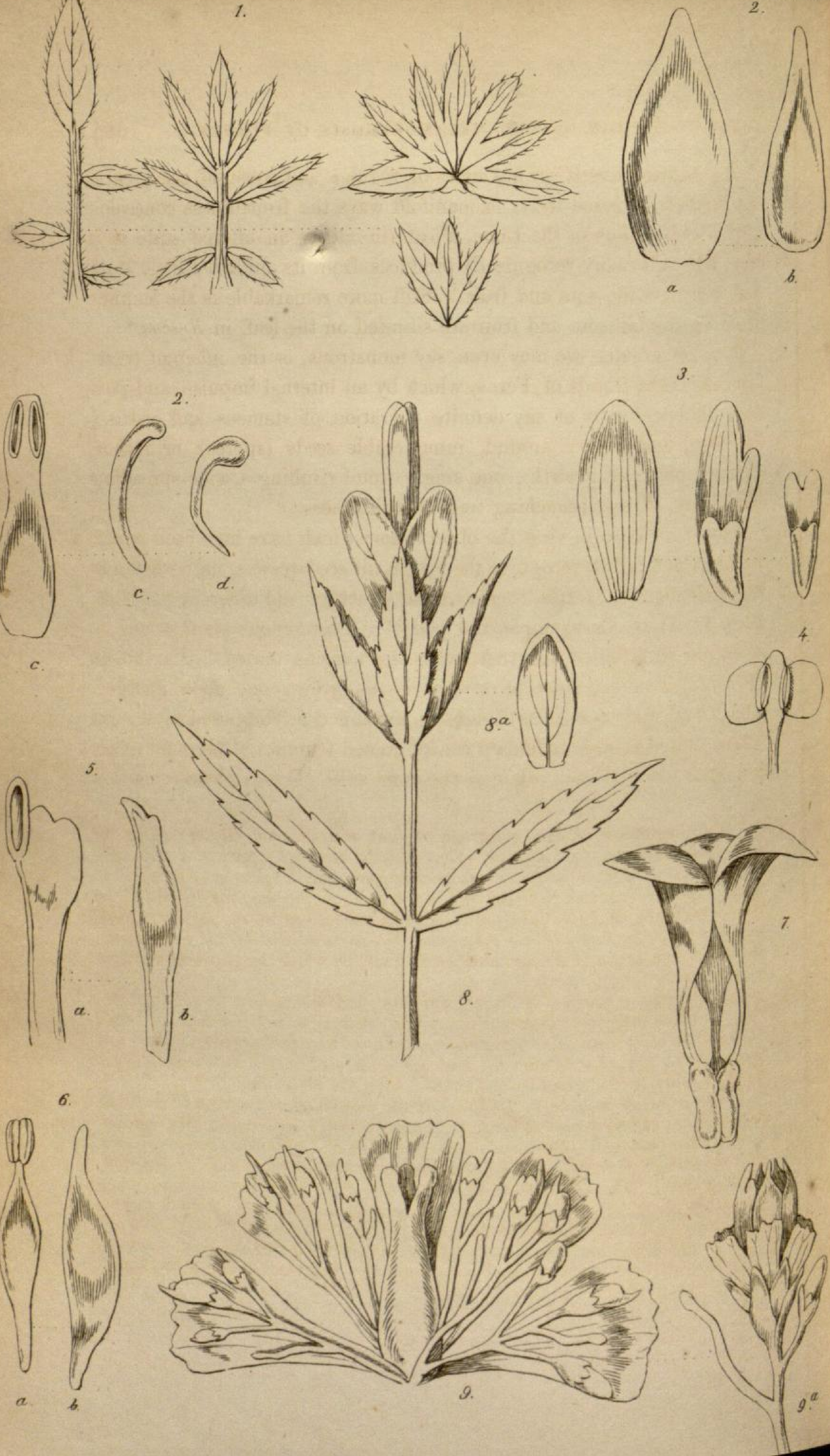
X. *Of the Fruit.*

74. We shall soon perceive that the fruit is of like origin with the previous organs, and subject to the same laws. We here speak more particularly of those seed-vessels which enclose so-called covered (angiospermous) seeds, or, more correctly, which are formed for the development of a larger or smaller number of fertilized seeds within them. It will be easy to show that these seed-vessels may be explained by the nature and organization of those parts of the plant which we have already considered.

75. Here again retrogressive Metamorphosis reminds us of Nature's law. In Pinks, for example, the very irregularity of which makes them such familiar and favourite flowers, it not unfrequently happens that the capsule assumes the appearance of sepals, and the styles shorten. The capsule of the Pink has even been transformed into a true and perfect calyx; little remnants of the styles and stigmas remaining attached to the tips of the divisions, whilst in the centre of this second calyx, a more or less perfect corolla was developed instead of seed.*

* See § 105.

Tab II



76. Nature herself, in instances of regular and constant occurrence, has further disclosed to us in manifold ways the fruitfulness concealed in the leaf. Thus in the Lime, a leaf (in rather an altered state it is true, but still easily recognized) produces from its midrib a little stalk with a perfect blossom and fruit. Still more remarkable is the manner in which the blossom and fruit are situated on the leaf, in *Ruscus*.*

77. Yet greater, we may even say monstrous, is the inherent fruitfulness of the fronds of Ferns, which by an internal impulse, and perhaps independently of any definite operation of stamens and pistils,† develope, and scatter around, innumerable seeds (spores), or rather, germs capable of growth; one single frond rivalling a wide-spreading plant, nay, a large branching tree, in fruitfulness.

78. If we keep in view the observations which have now been made, we shall not fail to recognize the leaf in all seed-vessels, notwithstanding their manifold forms, their variable structure, and different combinations.‡ Thus, for example, the pod of a Leguminous plant would be a simple leaf folded together, with its margins united. The husks (*Schoten*) would consist of several leaves grown one upon another. Compound pods (capsules) might be explained as composed of several leaves united round a common centre, joined together at their margins, but open towards each other on the inner side. This is obvious enough

* The illustrations of this paragraph are not well chosen. In the case of the
Lime-tree, the flower-stalk is simply adherent to the bract for a portion of its length,
while the so-called leaves of *Ruscus* are more properly considered as leaf-like branches.
Some, however, contend that the leaf-like organs, on the margins of which the
flowers are borne, in *Xylophylla*, are truly to be regarded as leaves, and not as phyl-
loid branches. In *Bryophyllum calycinum*, *Nymphæa micrantha*, and many Ferns,
the leaves give origin to a great number of buds, by which the plants may be pro-
pagated.

† The recent researches of Nägeli, Suminski, and others, have proved the exist-
ence of organs analogous to stamens and pistils (antheridia and pistillidia) in Ferns,
as well as in other so-called Cryptogamous plants, and have further shown that no new
spores can be formed until after the contents of the pistillidium have been fertilized
by the spermatozoids formed in, and emitted from, the antheridia.

‡ This principle is made by De Candolle the foundation of a system of classifica-
tion of fruits and seed-vessels, which is in many respects the simplest and best that
has yet been proposed. The more recent researches of Lestiboudois completely con-
firm the opinion that the carpels are homologous with leaves. (Ann. Sc. Nat. Bot.
1855, p. 242.) The double-flowered Cherry has pretty constantly its carpels exist-
ing in the form of small leaves, and the records of teratology afford numerous
instances of a similar foliaceous condition of the carpels. (Moquin-Tandon, 'Térato-
logie Végétale,' p. 204; Brongniart, 'Archives du Musée,' tom iv. p. 43, etc. etc.)
That the pistil may sometimes be formed from the dilated extremity of the branch
was not suspected in Goethe's time.

when after the ripening of the seed the capsule bursts asunder; each part then having the appearance of an open legume or pod. It is also shown by different species of the same genus; for instance, the capsules in *Nigella orientalis* consist of pods partially united and collected round an axis, while in *N. Damascena* their union is complete.*

79. This resemblance to the leaf is most difficult to discern when nature produces the seed-vessel either in a soft and succulent, or in a hard and woody state; but it will not elude our observation when we have once learnt to trace it through all its transitions. It is sufficient here to indicate the general idea, and by a few examples to show nature's unity of design. The manifold varieties of the seed-vessel will afford us matter for future and deeper consideration.

80. The connection of the seed-vessel with the preceding organs is also shown in the stigma, which in many instances is situated immediately upon the germen and is inseparably united with it. We have before pointed out the relation of the stigma to the leaf, and will here mention but one more instance, namely, the Double Poppy, in which the stigmas are changed into delicate-coloured petals.†

81. The last and greatest instance of expansion effected by the plant in the course of its growth, is seen in the fruit, which is often great, nay monstrous, both in internal power and in outward form. Since, after fructification, it generally increases in size, it would appear that whilst the seed, now in a more perfected state, draws those juices from every part of the plant which its own growth demands, they become centred in the fruit; by which means its vessels are nourished, enlarged, and often swollen and expanded to the greatest extent. That refined gases have a great share in this, may be inferred from what has been previously stated; the fact that the distended pods of the bladder-nut (*Colutea arborescens*) contain pure gas, has been established by experiments.‡

* Wolf. N. Comm. Acad. Petrop., *op. cit.*, expresses precisely the same opinion as to the nature of the seed-vessel.

† See Linn. 'Prolepsis,' § 9. In the 'Gardeners' Chronicle' of August 18th, 1855, there is a figure of a *Nymphæa*, in which, in addition to other singular changes, the stigmas are replaced by leaves. In *Stigmatophyllon* and many *Malpighiaceæ*, as well as in some other plants, the stigmas are very like leaves or petals (see tab. xi. fig. 7).

‡ If by pure gas, oxygen is meant, the fact is very doubtful; latterly, however, Matteucci has detected carbonic acid gas in these pods; but the presence of either of these gases would hardly afford any assistance towards explaining the enlargement of the seed-vessel.

XI. *Of the immediate Covering of the Seed.*

82. We find the seed, on the contrary, in the highest degree of contraction, but internally perfect. It may be perceived, in various seeds, that transformed leaves constitute their first covering, that they more or less adapt this covering to their shape, and in most instances that they have the power of closely attaching it and of entirely changing its form. Having seen above, that many seeds are developed in and from a single leaf, we need feel no surprise that a single embryo should clothe itself with a leafy covering.*

83. We see in many winged seed-vessels traces of such modified leaves imperfectly fitted to the seed,—in those, for instance, of the Maple, the Elm, the Ash, and the Birch. The Marigold affords us a very remarkable example, in its three circles of differently-shaped seeds (fruits), of the manner in which the embryo gradually contracts a covering of larger dimensions than itself, and closely adapts it to its own form. In the outer series the seed-vessel still retains a shape resembling that of the leaflets of the involucre, except that the rudimentary seed occasions a strain on the midrib, and curves the leaf, the inner curved surface being longitudinally divided by a membrane into two parts.

In the next circle a still further change takes place; the little leaf is both narrower and shorter, the membrane has entirely disappeared, and the rudimentary seed is more plainly shown at the back, on which moreover little excrescences are now perceptible; these two circles appear to be either not at all, or imperfectly fructified. In the third circle the curved shape of the seed is undisguised, the covering fits closely, and all its ridges and excrescences are complete.† Here we see a fresh

* For instances of the reversion of seeds or ovules to leaves, see Lindley, 'Elements of Botany,' p. 88; Moquin-Tandon, 'Tératologie Végétale,' p. 205, etc. It can hardly be said that the morphology of the coats of the ovule or seed is yet understood. While there is much evidence to show their foliar origin, there is also much in favour of their intrinsic axial nature. See A. Braun, Mém. sur les Transform. de l'Ovule Végétale, etc.; Ann. Sc. Nat. 1860, tom. xiv. 4me série. Hooker on ovule of *Welwitschia*, Trans. Linn. Soc. vol. xxiv. p. 27; Griffith in Lindl. Veg. King. p. 143.

† In the Marigold the achenia of the outer or ligulate florets are, as Goethe describes them, polymorphous; his account of them, though strictly correct in the main, would not be very intelligible to botanists not familiar with the plant. The fruits in question are in two or three rows, frequently surmounted by a beak, all more or less curved, and the outer ones especially provided with three leafy wings, two projecting from the margins, and the third from the middle of the inner surface, which it "divides into two parts." In *Tripteris*, a South African genus closely allied to *Calendula*, the fruits are even more decidedly three-sided and three-winged.

instance of the contraction of an expanded leaf-like organ, occasioned too, no doubt, by the internal strength of the seed, just in the same way as we have seen the petal contracted by means of the anther.*

XII. *Retrospective and Progressional.*

84. Thus far, then, we have carefully followed nature's footsteps; we have traced the outward form of the plant through all its transformations, from the period of its development from the seed till the seed is produced anew, and without pretending to investigate the hidden springs of impulse in nature's operations, we have directed our attention to the outward indications of those powers by which one and the same organ is gradually transformed. That the thread of the argument might be closely followed up, we have throughout spoken only of annual plants; we have simply observed the transformation of the leaves developed at the nodes, and from them have deduced every variety of form. But it will now be requisite, in order to give due completeness to this inquiry, to speak of the buds, which are inconspicuously situated at the base of each leaf; which, under certain circumstances, are developed, and under others seem entirely to disappear.

XIII. *Of Buds and their Development.*

85. Every node is endowed by nature with the power of producing one or more buds. These are developed in proximity to the accompanying leaves, which seem to prepare the way for and bring about the formation and growth of the buds.

86. In the successive development of one node from another, in the formation of a leaf at each node and of a bud adjacent to it, consists the primary, simple, and slowly-progressing process by which vegetable life is propagated.

87. It is well known that such a bud shows great similarity in its operation, to the ripe seed; and that, of the two, the entire form of the future plant may be often better recognized in the bud than in the seed.

88. Although the point at which the root will be developed is not so

* In this and the preceding section there is a little confusion between true seeds and those seeds to which the pericarp is, when ripe, inseparably adherent; these latter were not distinguished from ordinary seeds in Goethe's time. The argument is not affected by this confusion of parts.

easily detected in the bud, it is nevertheless present no less than in the seed; and, especially under the influence of moisture, the root is easily and rapidly produced.

89. The bud requires no cotyledons, because it is connected with the parent plant (now in a state of complete organization), and receives nourishment from it so long as this connection lasts; when separated from it, nourishment is supplied either by the plant on which it is grafted, or if planted in the soil, by roots which are immediately formed.

90. The bud is composed of nodes and leaves more or less developed, by means of which the plant continues to increase in size. Thus we may consider the lateral branches which arise from the nodes, as distinct little plants established on the parent, in the same way as the parent plant itself is established in the soil.*

91. The resemblance and the difference which exist between the seed and the bud, have been often, and especially of late, the subject of such able and exact investigations, that we can but appeal to them here with unqualified approbation.†

92. We will but state what follows. Nature makes an obvious difference in highly-organized plants between buds and seeds; but if we descend to plants of a simpler structure, the difference between them is imperceptible to the eye of even the most acute observer. There are unequivocal seeds, and there are unequivocal propagative buds; but the point is a purely ideal one, at which buds which simply push their way out from the parent plant and separate from it without any apparent cause, become one, as regards their inherent functions, with fertilized and disengaged seeds.

93. Having well weighed these things, we may venture to infer that

* The individuality of the buds seems to have been suspected by Hippocrates, who remarked the similarity between the branch and a small tree,—

'Αλλ' αὐτὸς ὁ κλάδος ἐστὶν ὥσπερ καὶ τὸ δένδρον ἔχει.—*De Natura Pueri.*

The doctrine that a plant is a compound being, a combination of individuals, has been supported in later times by La Hire, Goethe, Darwin, Du Petit Thouars, De Candolle, Gaudichaud, and others; while Sars, Steenstrup, Owen, Forbes, etc., among zoologists, have indicated analogous phenomena in the animal kingdom. These authors consider the formation of a series of buds as a process of vegetative reproduction alternating with, or intervening between, that which is the result of the sexual process. See Owen on Parthenogenesis; Forbes, 'Monograph of the Naked-eyed Medusæ,' p. 87; A. Braun, 'Rejuvenescence in Nature,' Ray Society Transl. 1853.

† Gærtner, 'De Fructibus et Seminibus Plantarum,' cap. 1.

seeds, whilst they differ from the newly-developed bud (*Auge*) in being concealed within a seed-vessel, and from the more mature bud (*Gemma*) in the discernible causes of their formation and subsequent separation from the parent plant, are yet nearly related to the bud at each of these periods.

XIV. *On the Formation of Composite Flowers and Fruits.*

94. We have thus far endeavoured to explain by the transformation of the stem-leaves,* the formation of solitary flowers, and also of those seeds which are produced within a closely adherent covering. It will appear, on a careful examination, that in these instances the (axillary) buds are absent, and that, on the contrary, the possibility of such a development is altogether out of the question. But in explaining Composite flowers and fruits (whether the receptacle be conical, cylindrical, discoidal, or of any other form), we must look to the development of buds for assistance.

95. Now we commonly see stems which, instead of reserving their energy and making a long preparation for the production of a single (terminal) flower, develope blossoms at their nodes, and proceed uniformly in this manner to the very tip. But the phenomenon thus shown is susceptible of explanation by the theory propounded above. All flowers developed from axillary buds are to be regarded as perfect plants, situated in the same way on the parent plant as the parent plant is situated in the soil. But as the juices received from the nodes are in a refined state, the very first leaves of a little branch are much more defined in shape, than the earliest leaves which, in the parent plant, immediately succeed the cotyledons; nay, even the immediate formation of the calyx and corolla may not unfrequently occur.

96. Even the blossoms thus produced from (axillary) buds would have become branches by a more copious supply of nourishment, and in their turn parent-stems to another set of buds.†

97. During the successive development of such blossoms at the nodes, we perceive the same change taking place in the stem-leaves which we before observed during the slow transitional process by which

* Had Goethe written "modification," his theory would not have met with so much opposition.

† The flowers are occasionally more or less converted into branches. See Lindley's 'Elements of Botany,' p. 62; Moquin-Tandon, 'Tératologie Végétale,' p. 366, etc.

the calyx was produced. They gradually diminish in size, till at last they almost entirely disappear; the leaf-form is more or less lost in their diminished state, and they are called bracts. The stem becomes attenuated in the same proportion, the nodes approximate, and all the phenomena before pointed out take place, except that there is no decidedly terminal flower, because Nature has already fulfilled her task at each successive bud.

98. Now when we have well considered a stem thus adorned with a flower at every node, we shall be in a condition to understand a *composite flower;* and the more easily if we remember what was stated above concerning the formation of the calyx.

99. Nature forms a common calyx (involucre) out of a number of leaves which she draws close together and arranges round an axis. With the same strong impulsive growth she developes, if we may so speak, *a stem without an end, producing all its axillary buds simultaneously, and in the form of flowers, which are placed in the closest possible proximity*, each separate floret fructifying its own germen. Nor are the node-leaves always lost in this instance of excessive contraction; in Thistles, (as for instance in *Dipsacus laciniatus*,) the leaflet faithfully accompanies the floret which is developed from the contiguous bud. In many Grasses also, each floret is accompanied by a similar kind of leaflet, called a glume.

100. We thus perceive how *the seeds produced in a composite flower may be considered as true buds, formed and developed by means of the male and female organs.* The examination of the growth and manner of fruiting of various plants will establish this view.

101. This being so, we may easily draw the same inference as to the seeds produced in the centre of a single (non-composite) flower, whether they are enclosed within a seed-vessel, or not.* For the argument is the same, whether a solitary flower encloses a compound ovary, whose united pistils imbibe the fertilizing moisture from the anthers, and convey it to the ovules; or whether a one-seeded ovary is provided with its own pistil, anthers, and corolla.

102. We are convinced that with a little practice it would not be difficult to explain in this manner the manifold forms of fruits and

* In the latter instance Goethe probably had in view the one-seeded achenes of Labiates and Borages, and other plants ranked as *gymnospermous* in his time. See note to § 83.

flowers. All that is requisite is to be able to work out the aforenamed ideas of expansion and contraction, approximation and anastomosis, as easily as we work out rules of algebra, and to know how to apply them in their proper places.* And, as much depends upon the exact observation and comparison of the different gradations through which nature passes, both in the formation of genera, species, and varieties, and in the growth of individual plants,—a series of illustrations exhibiting these gradations, with explanations expressed in botanical terminology, would be both welcome and useful.† We will now adduce two instances of proliferous flowers, having an important bearing upon this theory.

XV. *A Proliferous Rose.*

103. All that we have been endeavouring to grasp by the aid of thought and reason is shown in the clearest manner in the instance of a proliferous Rose. The calyx and corolla are developed and arranged round the axis, but instead of the contracted receptacle with its stamens and styles in the centre, the stem, variegated with green and red, again ascends; and on it are successively developed, unexpanded, dark-red petals of a smaller size, on some of which are visible traces of anthers. The stem goes on growing, prickles appear on it, the *alternate* petals continue to diminish in size, and change at last into stem-leaves, also variegated with red and green; a series of regular nodes is formed, and from their buds small imperfect rose-buds burst forth.‡

104. This same example also affords us a visible proof that, as has been before explained, the outer border of the calyx may be considered as a number of approximated leaves (*folia floralia, bracteæ*); for the calyx here consists of five perfect, compound leaves, of three or five

* "Every plant has its proper vital lines for these vibrations of the metamorphosis, the constructive representations of which lines will make clearly conceivable characters which botanists have only seized in the most fragmentary manner, or have felt obscurely as something indescribable in the habit." (Braun, 'Rejuvenescence,' Henfrey's translation, p. 83.) No plant is more suggestive, or more worthy the attention of morphologists than the *Welwitschia*, described with so much care and acumen by Dr. Hooker in the paper above referred to.

† Goethe's obscure and unscientific phraseology has constituted one of the main difficulties the translator has had to encounter in rendering the essay into English; and moreover it may have afforded a reason for the little inclination scientific men had at first to entertain Goethe's opinions.

‡ Masters, 'On Median and Axillary Prolification in Flowers,' Transact. Linn. Soc. vol. xxiii. pp. 359–481, c. icon.

leaflets, resembling in all respects those which the rose-branches produce at their nodes.

XVI. *A Proliferous Pink.*

105. We have in this proliferous Pink a perfect flower, with a calyx and a double corolla, and in the centre a somewhat imperfect capsule. From the sides of the corolla,* four other perfect flowers are developed, separated from the parent-flower by stalks of three nodes or more in length. Each of these has also a calyx and double corolla, formed not so much from separate (typical) leaves, as from a crown of (typical) leaves, with the petioles united, or rather of a series of (typical) flower-leaves developed around an axis and united on a little branch. Notwithstanding this monstrous development, the filaments and anthers are sometimes present. In some the capsules are produced with their styles, in others the capsule is leaf-like, or rather like a calyx, and contains the rudiments of another double corolla.†

106. In the Rose we have, as it were, a half finished flower, from the centre of which the stem again shoots upwards, bearing stem-leaves as before; in this Pink, with a well-formed calyx and a perfect corolla, and a *capsule situated in the very centre*, we have *buds developed within the circle of the petals*, producing actual branches and blossoms. Thus, both instances lead us to the conclusion, that nature ordinarily terminates the period of growth in the blossom, and so, as it were, closes her account, that by thus preventing the possibility of gradual and indefinite growth, she may arrive at her object by a shorter way in the formation of the seed.

XVII. *Linnæus's Theory of Anticipation.*

107. If I have sometimes stumbled in a path which one of my predecessors, though exploring it under the guidance of his great master,

* *Query*, From the receptacle within the corolla?

† The Pink described in this paragraph seems to be the same as that mentioned by Goethe, in his history of his botanical studies, as having greatly contributed to develope the fundamental idea of the metamorphosis of plants. At § 75 is a good description of the most usual kind of proliferous Pink, of which numerous instances are cited by Moquin-Tandon, 'Tératologie Végétale,' p. 366. M. Gingins-Lassaraz cites, as an illustration of this present paragraph, the case of *Dianthus prolifer*; but the description given by Goethe does not correspond to that flower.

A Pink affected with axillary prolification, and figured in my paper on axillary prolification before cited, seems to resemble closely the one described by Goethe. See also tab. xi. f. 9, 9*a*.

describes as difficult and hazardous;* if I have not entirely succeeded in levelling it, and clearing it of every obstacle for those who come after me, I may yet hope that this endeavour will not be altogether fruitless.

108. It will be proper here to mention the theory by which Linnæus sought to explain the phenomena of which the foregoing pages treat. Things such as those therein discussed, could not have escaped his penetrating eye; and if we are now able to advance, where his progress was checked, we are indebted for this to the many observers and thinkers who have removed obstacles from our path, and overcome prejudices. An exact comparison of his theory with that above propounded, would detain us too long. The scientific reader will easily compare them for himself, and such a comparison must necessarily enter too much into detail, if made intelligible to those who have never considered the subject. We will only point out briefly what hindered Linnæus from making further progress, and prevented his reaching the goal.

109. In the first place, his observations were made on trees;† long-lived plants of a complicated nature. He noticed that a tree planted in a large pot and copiously supplied with water, produced branch after branch for several years in succession, but that if planted in a smaller pot, it speedily produced both flowers and fruit. He perceived that a development, which is generally gradual, may thus be forced to take place at once. He therefore designated this operation of nature by the name of "Prolepsis,"—anticipation,—because the plant appeared to anticipate by six years, the six steps of which we have spoken above. He chiefly explained his theory by the buds of trees, without paying any particular attention to annual plants, else he would have been aware that his theory did not hold equally good with regard to them. For according to his teaching, we must assume that all annual plants were properly intended by nature to be six years in coming to perfection, but that this longer period is suddenly anticipated at the time of blossoming and fruiting, after which they as suddenly wither.

* Ferber, in Præfatione Dissertationis secundæ de Prolepsi Plantarum.

† "Si arbusculam, quæ in olla antea posita, quotannis floruit et fructus protulit, deinde deponamus in uberiori terra calidi caldarii, proferet illa per plures annos multos ac frondosos ramos, sine ullo fructu. Id quod argumento est, folia inde crescere, unde prius enati sunt flores; quemadmodum vicissim, quod in folia nunc succrescit, id natura ita moderante, in flores mutatur, si eadem arbor iterum in olla seritur." (Linn. 'Prolepsis,' § iii.)

110. We, on the contrary, have begun by making observations upon annuals, and an application of the argument to longer-lived plants may be easily made; for an opening bud on the oldest tree may be regarded, in some sort, as an annual plant, although capable of longer duration, and produced from an old stem.

111. The second cause which checked the further progress of Linnæus was, that he regarded the different circles enclosed one within the other in the stem of a plant [namely, the outer and the inner bark, the wood, and the pith], as equally active and essential parts, alike instinct with life; and that he attributed the origin of the flower and fruit to these different rings of the stem, because, like them, they encircle each other, and appear to be developed one from the other.* But these were only superficial observations, which could never stand the test of a closer examination. Not only has the wood within become too hard, but the outer bark, in long-lived trees, is both too hard on the outer side, and too slightly connected with the inner portion of the stem, to be the cause of any fresh development. In many trees it breaks away and falls off, and in others it may be stripped off without any injury to the tree, so that it cannot produce either the calyx or any other living part of the plant. It is in the second bark (*liber*) that all the power of life and growth resides; in proportion as this is injured, the growth of the plant is interrupted; it is this also, as close observation will convince us, which produces the external organs in succession on the stem, or simultaneously in the flower and fruit.† Linnæus only ascribed to it the subordinate office of producing the petals. The important production of the stamens, on the contrary, was attributed to the wood; it is clear, nevertheless, that however durable this portion of the plant may be, which solidification has rendered inactive, it is dead as regards any vital action. But the most important office of all was reserved for the pith; that, namely, of producing the pistils and their numerous seeds. The doubts which have been raised as to the great importance thus ascribed to the pith, and

* Cf. Linn. 'Prolepsis,' § 7, 8. Wolff's account of the development of the flower, in his 'Theoria Generationis,' 1759, is much more in accordance with truth, and, with some slight exceptions, it is amply confirmed by modern observers. To Wolff undoubtedly belongs the merit of being the first to insist on the necessity of examining the development of flowers, and of being the first to give, from actual observation, a clear account of the process.

† See note to § 27. See also Trécul, Ann. Soc. Nat., 3me série, tom. xx. p. 211, and 4me série, tom. iii.

the reasons alleged against it, appear to me weighty and conclusive. The only causes which could have given rise to this notion, are the soft and undefined state (resembling that of pith or parenchyma) in which the pistils and fruit first make their appearance, and their position in the centre of the stem, where we are accustomed to see the pith.

XVIII. *Recapitulation.*

112. It is my wish that this attempt to explain the metamorphosis of plants, may not only contribute something towards the solution of this problem, but may give occasion to further investigations and results. The observations on which it is grounded, which were made at different times, have been collected and arranged by Batsch in his 'Anleitung zur Kenntniss und Geschichte der Pflanzen;'* and it will soon appear whether the step we have taken has brought us any nearer to the truth. Let us now review as briefly as possible the leading points in the foregoing essay.

113. When we consider the indications of vital powers existing in plants, we find them manifesting themselves in two different ways; first, by *growth* during the development of the stem and leaves; secondly, by *reproduction* effected in the flower and fruit. When we narrowly watch the growth of a plant, we see that as it mounts upwards from node to node, and from leaf to leaf, a kind of reproduction is going forward, differing from the *sudden* reproduction effected in the flower and fruit, inasmuch as it is a series of *successive* and distinct developments. This power of gradual growth by the production of buds, is most closely related to that which effects reproduction at once. Under different circumstances a plant may, on the one hand, be forced continuously to produce leaf-buds, or, on the other, to develope the flower. The former result is produced by an accumulation of crude juices, the latter by the preponderance of the subtile powers latent in the plant.

114. The manner in which the two different kinds of reproduction take place, has been indicated by the application of the term *successive* to reproduction by leaf-buds; whilst we spoke of reproduction by the flower and fruit as *sudden*. A plant, whilst it is producing leaf-buds, increases more or less in size, it developes a stalk or stem, the nodes are generally separated by perceptible intervals, and leaves expand in all directions. But, on the contrary, when a plant produces the

* 1 Theil, 19 Capitel.

flower, all the parts become contracted, increase in height and breadth has ceased, and all the organs, now in an extremely contracted state, are developed in close proximity.

115. But whether a plant produces leaf-buds, flower, or fruit, it is still *the selfsame organ* which is carrying nature's laws into effect, though performing different offices, and disguised under different forms.* The same organ which on the stem expands as the leaf, exhibiting every variety of form, is contracted in the calyx, again expands in the petal, and is once more contracted in the stamens and pistils, to expand for the last time in the fruit.†

116. This operation of nature is combined with another, by means of which *different organs are assembled round a common centre*, in a definite number and order, subject however to variation in many flowers, and under certain circumstances.

117. An anastomosis likewise co-operates in the formation of the flowers and fruit, by means of which the delicate organs of reproduction are brought into the closest connection with each other, either through the whole period of their duration, or at least during a part of it.

118. But these phenomena of *approximation*, *centralization*, and *anastomosis* are not peculiar to the flower and fruit; we may perceive something of the same kind also in the cotyledons.

119. Now in the same way as we have endeavoured to deduce all the apparently different organs of a plant, whether producing buds or flowers, from one and the same organ,—namely, the leaf, which is usually developed at the nodes, we have further ventured to refer to the same origin, the fruit (seed-vessel), within which the seeds lie safely enclosed.

120. It was obviously necessary to adopt some general term by which to indicate the one organ which we see metamorphosed under so many different forms, and which we could also employ in comparing these variations with each other. The thing to be now aimed at is to keep habitually in view the two contrary directions, if we may so speak, in

* Dr. Dresser's opinion that the sepals, petals, etc., are often modifications rather of the petioles than of the laminæ of leaves, though undoubtedly correct in many instances, by no means militates against the truth of Goethe's propositions. See Dresser, 'Rudiments of Botany,' pp. 277, 299.

† See Wigand, 'Kritik und Geschichte der Lehre von der Metamorphose der Pflanzen,' 1846, p. 118.

which these variations are developed. For we may say with equal truth that a stamen is a diminished petal, or that a petal is an expanded stamen; that a sepal is a diminished stem-leaf in a more refined condition, or that a stem-leaf is a sepal in a state of expansion occasioned by crude juices.

121. Thus also it is immaterial whether we speak of the stem, as the flower and fruit in a state of extension, or whether, as above, we regard the flower and fruit as a shortened stem.

122. At the end of this treatise I have taken into consideration the development of *buds*, and have endeavoured to explain by their means the nature both of composite flowers, and of those seeds which are unprotected by a seed-vessel (*unbedeckte Fruchtstände*).*

123. It has been my object in what I have here brought forward, to state, as clearly and fully as possible, a view, which I think carries much conviction with it. But should the evidence appear to be insufficient, or should my theory meet with much opposition, and appear incapable of universal application, it will become so much the more incumbent on me to note all suggestions, and at some future time to discuss these subjects more minutely and circumstantially, that by giving greater perspicacity to my view, I may earn for it a more universal approbation than I can expect from this first essay.†

Explanation of Plate XI.

Fig. 1. Passage of leaves to bracts in *Anthyllis vulneraria*. 2. Passage of sepals (*a*) to petals (*b*), stamens (*c c*), and stigma (*d*), in *Nymphæa blanda*. 3. Transition from sepal to tubular petal or nectary in *Eranthis hyemalis*. 4. Anther of *Pterandra*. 5. *a*, Stamen, and *b*, style of *Canna Indica*. 6. *a*, Stamen, and *b*, pistil, of *Thalictrum*. 7. Stigmas of *Brachypteris*. 8. Exceptional flower of *Epilobium hirsutum*, in which all the floral whorls are replaced by leaves; *a*, foliaceous petal from the same. 9. Exceptional flower of *Dianthus*, sp. The sepals and some of the petals are removed, to show stalked flower-buds occupying the position of the stamens. 9*a*. Stalked flower-bud from the same; the stalk has a petaloid strap-like scale projecting from it; the sepals and petals are increased in number, the stamens abortive, and the carpels open and disjoined, and in this case destitute of ovules.

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* See note, §§ 83, 101.

† For a brief sketch of the origin and progress of the theory of vegetable morphology, prior to the publications of Wolff, Linné, and Goethe, as well as for an attempt to show what share each author had in the establishment of the doctrine, the reader is referred to an article in the Brit. and For. Medico-Chirurgical Review, January, 1862, entitled "Vegetable Morphology," its history and present condition, by Maxwell T. Masters.