no means evident. Physiologists are as yet but partially informed, satisfying themselves with the general statement, that all these products are either necessary to the growth, propagation, or preservation of the plant, or are excreted to maintain it in a healthy condition.

METAMORPHOSES OF PLANTS.

261. *The Metamorphoses of Plants* forms one of the most interesting sections of Vegetable Physiology. Technically, it is termed *Morphology*—that is, a consideration of the changes and transformations which various parts of plants undergo, either from natural or artificial causes. We know, for instance, that many plants are made to change their appearance and qualities by cultivation; that by grafting, hybridizing, and so on, the gardener can change the size, colour, and qualities of his fruits and flowers; and that analogous changes take place in a state of nature, such as the conversion of leaves into petals, and leaves and branches into thorns and spines. It is also well known that flowers become double by changing their stamens into petals; and it is from a knowledge of these facts that botanists have asserted that all the appendages of the stem or ascending axis are modifications of a single organ, and may be considered *as leaves adapted to a special purpose.* This doctrine, at first broached by Linnæus, and subsequently expounded by the celebrated Goëthe, is now very generally adopted. It is usual to treat of this subject under two heads, namely, *regular* metamorphosis, or that connected with the structure of all vegetables; and *irregular* metamorphosis, or that which influences only a particular class of plants, or parts of those plants, and which occur under peculiar circumstances.

REGULAR METAMORPHOSIS.

262. *Regular metamorphosis* embraces those transformations which are applicable to all vegetables. It presumes

277. Define morphology, and varieties named.
278. How classified?
279. Define regular metamorphosis.

that, if the organ can be transformed into another, there is an identity in their origin and nature. If, for example, leaves are sometimes converted into bracts, bracts into a calyx, and the calyx into a corolla, then it is almost self-evident that the corolla, calyx, and bracts, have the same origin as the leaves. Regular metamorphorsis seeks for facts to establish this doctrine, namely, that all the appendages of a plant have a common origin with the leaf, and may therefore successively assume the form and appearance of that primary organ.

263. *All the appendages of the stem are modifications of leaves*, transformed to subserve some special purpose. The first protrusion of the plumule from the embryo is leaf-like, subsequently true leaves are developed, and from a succession of these are formed the stem. The branches of the stem take their origin from leaf-buds, and are again clothed with branches and leaves by the same process as in the main stem. As a branch proceeds towards the point of fructification, the leaves assume the form of bracts, these again are succeeded by the leaf-like sepals of the calyx, and next by the petals of the corolla. Within the petals are the stamens, which sometimes assume a leafy form, next the pistil, and ultimately the seed-vessels. Even the seeds are but leaves in another form, embalmed and preserved, as it were, for the reproduction of another plant; and in many, such as the beech-mast, the leaflets of the embryo may be distinctly seen, folded and imbedded in their future nutriment. Thus, the growth and reproduction of plants may be regarded as a circle of leaf-like changes, the leaf, or some modification of it, being in all cases the organ which administers to the functions of vitality.

264. *In stipules and bracts, the leafy origin* is abundantly evident. The former are more or less developed in all plants, and may be considered as rudimentary leaves, or parts of the leaf. Bracts, again, are always intermediate between true leaves and the calyx, forming the boundary between the period of growth and that of fructification. In

280. What are modifications of leaves?
281. What of stipules and bracts, sepals and petals?

some roses, for example, the bracts are exactly similar to the leaves, while in the tulip, they frequently partake both of the colour and texture of the sepals. Bracts, like true leaves, have buds in their axillæ, as may be seen in the rose and common daisy. Bracts also mark the transition from growth to inflorescence, by their mode of arrangement. Leaves may be alternate or whorled on the stem, while the floral appendages are always whorled or verticillate: the bracts generally represent the transition to this whorled arrangement.

265. *That there is no essential difference between the sepals of the calyx and the petals of the corolla* is evident from the sepals being frequently coloured, and forming the most beautiful portion of the blossom. In the monkshood, the blue part which forms the flower is botanically the calyx, the petals being entirely concealed under the hood. In the fuschia, the bright scarlet part is the calyx, and the small purple petals within, the corolla; while in the tulip and crocus, the sepals and petals are all coloured alike, so that it would be impossible to distinguish one from the other, did not the sepals grow a little lower on the stem. In many plants, the petals and sepals are identical in colour, texture, and odour; and when the perianth is single, they seem to be combined.

266. *In like manner there is no physiological difference between the petals and leaves.* Both have a framework of veins, the interstices of which are filled up with cellular tissue, and both have an epidermis furnished with stomata. The absolute change of leaves into sepals, and thence into petals, may be occasionally seen in the tulip, the bracts or floral leaves of which are sometimes partially coloured, like the proper petals of the flower.

267. *The construction and arrangement of the stamens point to the same leafy origin* as the corolla and calyx. The stamens which form the third whorl, or series of fructification, have occasionally their filaments dilated and leaf-like, as in the white water-lily and barberry. In many cases—

282. How is the leaf shown to be the fundamental structure?

such as the double roses, anemones, ranunculuses—a transition is observable from the outer petals of the corolla to the true stamens; the petals gradually becoming smaller, and ultimately assuming the colour and form of stamens.

268. *The sepals, petals, and stamens, always correspond in number.* For example, if there be five petals, there will be five sepals, either separate, or slightly adhering together, and generally the same number of stamens. Sometimes, however, the stamens are more numerous; but they always consist of some multiple of the original number of petals—as, for instance, when there are five petals, there will be five, ten, or twenty stamens. Five, three, or six, are the most common number for petals; four is very rare; and seven has never yet been met with.

269. *The fourth series, or concentric whorl of fructification, is the discus,* which is so frequently absent, and of so obscure a nature when present, that few morphologists take it into their consideration. Dr. Lindley seems inclined to regard it as a modification of the stamens, and consequently partaking of the nature of that fundamental organ, the leaf. "M. Duval," says he, "has noticed half the disk of a cistus bearing stamens; and a variety of instances may be adduced, of an insensible gradation from the stamens to the most rudimentary state of this organ."

270. *The pistil and ovary,* which form the last of this concentric series, seem formed in the same way by the metamorphosis and union of leaves. Many pistils have a laminated, or blade-like shape, and the stigma of some, such as the iris, is leafy (see fig. 66). The leafy origin of the ovary is still more perceptible—a follicle, for example, being evidently composed of one or two leaves folded, and adhering at the edges. The same may be said of other carpels; and even a pome (fig. 70) may be regarded as several leaves metamorphosed by an increase of cellular tissue, and united so as to form one continuous mass. The leafy origin of fleshy fruits is often very perceptible when newly formed, or when by some accident they are rendered abortive at this stage.

283. Name the various illustrations.

271. *What are called monstrosities in flowers,* furnish another evidence that the floral appendages are merely modifications of the leaf, or at least that the same structure is common to both. These monstrosities generally arise from some accidental circumstance operating, so as to change the flower-bud into a leaf-bud during the germination of the flower. Thus, if a plant be supplied with abundance of moisture and warmth, but with little sunlight, the growing point will be developed into a bud in the centre of the flower, and sometimes a second flower will be produced at the extremity. We also know, that removing a wild plant into a garden has a tendency to make the flowers double; because the richer soil affords so much nourishment, that enough of cellular tissue is produced to change the stamens into petals.

272. *Leaves and branches are frequently transformed into spines and thorns.* Indeed, thorns are regarded as leaf-buds which have been rendered abortive by some accidental stoppage of the sap, which prevents the addition of cellular tissue sufficient to form perfect leaves. Branches, which also take their origin from leaf-buds, may be arrested at a certain stage of their growth, so as to form spines instead of perfect branches; and such spines not unfrequently give birth to new leaf-buds and leaves, as may be seen in the common hedge-thorn.

273. *In conclusion*—"We see," says Dr. Lindley, "that there is not only a continuous uninterrupted passage from the leaves to the bracteæ, from bracteæ to calyx, from calyx to corolla, from corolla to stamens, and from stamens to pistillum—from which circumstance alone, the origin of all these organs might have been referred to the leaves—but there is also a continual tendency on the part of every one of them to revert to the form of the leaf."

IRREGULAR METAMORPHOSIS

274. *Of irregular metamorphosis,* or those changes which parts of plants, or classes of plants, may be made to assume

284. What of monstrosities in flowers?
285. Other transformations.
286. Define irregular metamorphosis.

little is absolutely known. In a state of nature, certain tribes are limited to certain localities, these situations being characterized by some peculiarity of soil and atmospheric influence. If the conditions of soil and climate to which they are subjected remain the same, the character of plants is nearly uniform or stationary; and this may be always said of them in their natural state. But if they be removed from a poor to a rich soil, from a dry to a moist habitat, from a warm to a cold climate, or *vice versa,* then their internal structure will undergo a change; and this change will manifest itself in one or other of their external characters. In some classes, this change is most evident in the roots and tubers; in others, in the stems and leaves; while in many, the organs of fructification (the flowers and fruit) are the parts most affected. Sometimes this change of situation merely produces a more luxuriant development of all the parts of a plant, without causing any abnormal growth of a particular organ. Cultivation, and other artificial treatment may be considered as the cause of these irregular metamorphoses, which assume in some plants a wonderful degree of permanency, and may be transmitted to successive races; though, generally speaking, if the artificial stimulus be not kept up, plants will return to their normal or natural condition.

275. *The changes which roots and tubers* can be made to undergo are numerous, and highly beneficial to man. The potato, for example, is a native of tropical America; and when found wild there, its tubers are small, and scarcely, if at all, edible; while in Europe, it has been rendered by cultivation one of the most valuable articles of food. The produce of an acre of wild potato could be carried in a single measure, while in Britain, the same extent will yield from forty to sixty bolls. Cultivation has also produced a thousand varieties of this tuber, varying in shape, size, colour, and quality: even in one year, a change of soil will sometimes cause a difference, not only in quality,

287. What of transplantation?
288. Name examples of the changes in roots and tubers.
289. Varieties in climate and effects.

but in colour and appearance. Beet, parsnip, and turnip, are also made to assume many varieties under judicious cultivation. The bulb of the latter, for instance, has, since the beginning of the present century, been metamorphosed into forms from globular to fusiform, in colours from white and yellow to purple and green, and in weight from a couple of ounces to twenty pounds. So, also, with the carrot, which in a wild state is a slender tapering fleshy root, of a yellowish-white colour, but which by cultivation increases in size, and assumes a deep red or orange colour. In the one case, the root is not much thicker than a common quill, in the latter, it becomes as thick and long as a man's arm. Nor are we aware of any limit to such metamorphoses; more numerous and more gigantic varieties may yet be reared by superior cultivation.

276. *The stem is less subject to irregular metamorphoses* than either the roots or tubers. It has been already stated (par. 31), that if a tree which is a native of mountains be placed in a valley, it grows more rapidly, and its timber becomes softer and of less value; and, in like manner, if the tree of a valley be removed to a mountain, it becomes of slow growth, and small dimensions, but produces timber remarkable for its toughness and durability. Generally speaking, stems in hilly regions became short and hardy, in low and moist situations long and of softer texture, in open plains firm and coloured, and in shady recesses slender and delicate. By cultivation, tall stems are for the most part rendered short, and short ones taller—the dahlia, for example, having been reduced to one-half of its natural height by garden culture. The cabbage, in its wild state, has a tough slender stem, which by culture has become fleshy and fusiform; and so also of many other culinary plants. Sometimes the stems of cultivated plants assume a double or triple appearance, as if two, three, or more individuals had been glued together. Stems in this state are said to be *fasciated*, or bundled, but are in reality single stems, and not a mere accidental adhesion of several individuals.

290. What of the stem? Illustrations.

277. *Leaves are subject to innumerable metamorphoses*, arising either from culture, change of season, disease, or injury by insects. From a thin and tough condition, they will sometimes become succulent, and roll inwards, forming what is called a *heart*, as in the common cabbage and lettuce. In others, the paranchyma and margin are produced in excess at certain stages of growth, so as to convert plain leaves into a puckered and irregular shape, as in the curled cress, curled savory, &c. Trees and shrubs with notched, lobed, and compound leaves (par. 103), will, by being transplanted to a rich soil and warm situation, become simple and entire; even pectinate leaves, under similar treatment, will become fleshy, and fan-shaped ones lobed. Sudden changes of weather, such as from excessively dry to wet, or the reverse, occasionally produces strange metamorphoses among leaves; so likewise do the injuries received from the stings and larvæ of insects.

278. *The metamorphoses which occur in the floral organs* are also very frequent; and on this feature depends all that variety and beauty which it is now so much the object of the florist to produce. These transformations consist in an increase of the petals, in a conversion of petals into stamens, and in some modification of the colour. What are called *double* flowers, and produced by a multiplication of the petals, as in the common varieties of the rose; and *full* flowers are those in which the multiplication is carried so far, as to obliterate the stamens and pistil. In a wild state, for example, the rose produces but a single row or verticil of petals, surrounding a vast number of stamens; but when cultivated, several rows of petals are formed at the expense of the stamens, which are proportionally diminished. "With regard to colour," says Dr. Lindley, "its infinite changes and metamorphoses in almost every cultivated flower can be compared to nothing but the alterations caused in the plumage of birds, or the hairs of animals by domestication. No cause has ever been assigned to these phenomena, nor has any attempt been made to determine the cause in plants.

291. Agencies operative upon leaves.
292. Varieties in flowers.

We are, however, in possession of the knowledge of some of the laws under which change of colour is effected. A blue flower will change to white or red, but not to bright yellow; a bright yellow flower will become white or red, but never blue. Thus the hyacinth, of which the primitive colour is blue, produces abundance of white and red varieties, but nothing that can be compared to bright yellow, the yellow hyacinths, as they are called, being a sort of pale yellow ochre verging to green. Again, the ranunculus, which is originally of an intense yellow, sports into scarlet, red, purple, and almost any colour but blue. White flowers, which have a tendency to produce red, will never sport to blue, although they will to yellow; the roses, for example, and the crysanthemums." For further remarks on the subject of colour in flowers, see par. 212–217.

279. *The changes which the fruit or seed undergoes* are also very numerous and obvious. Where, for instance, is there a native grain like wheat, or a native fruit like the apple? In a wild state, the seeds of our cereal grains (wheat, barley, oats, &c.) are thin and meagre; by proper cultivation, they are rendered large, plump, and full of farina, so as to become the most important articles of human sustenance. Numerous varieties of these grains, each differing in colour, flavour, durability, &c., are now raised by cultivation; so that, compared with their originals, their value is more than a thousandfold. The small globular sour crab apple of our hedges is the original of the numberless varieties of apple now cultivated by gardeners, each variety differing somewhat in size, shape, colour, and flavour. So also with the sloe, which is the parent of our purple, yellow, and white plums; with the wild cherry, and almost every species of cultivated fruits and seeds. Besides the changes which are steadily effected by cultivation, there are frequent sports in the fruit, as in the blossom or flower. In the orange, a second fruit is sometimes produced inside the outer, agreeing in all respects with the outer fruit; and in

293. Examples of floral transformation.
294. Changes of fruit and seed, examples.
295. Whether spontaneous or by cultivation.

the apple and cherry, double and triple fruits, analogous to fasciated stems, are frequently to be met with.

HYBRIDISM.

280. *The hybridism of plants* is closely allied to the subject of morphology, and is in fact a transformation of character produced by artificial means. As among animals two distinct species of the same genus will produce an intermediate offspring—such as the *mule*, which is the offspring of the horse and ass—so among vegetables two species belonging to the same genus can be made to produce a *hybrid;* that is, a new plant possessed of characters intermediate between its parents. This power of hybridizing is more prevalent among vegetables than animals; for the different species of almost every genus of plants are capable of producing this effect, if the pollen of one species be put upon the stigma of another. This union, however, can only take place between nearly allied species; it occurs rarely among plants in a wild state, but is quite common among cultivated species. According to modern botanists, the character of the female parent predominates in the flowers and organs of fructification of the hybrid, while its foliage and general constitution are those of the male parent.

281. *Hybrids have not the power of perpetuating their kind* like naturally distinct species. Mule animals, for instance, are uniformly incapable of procreation, unless with one of their parent species; so also with vegetable hybrids, which, though occasionally fertile in the second and third generations, have never been known to continue so beyond the fourth. If impregnated with the pollen of one of its parent species, a hybrid plant will give rise to a new hybrid, partaking more of the character of the original parent; and if this process be continued for two or three generations, the hybrid will ultimately return to the pure

296. What of the hybridism of plants?
297. Analogy from the animal kingdom.
298. Peculiarities of hybrids.

species. Thus, though hybrids are incapable of propagating themselves beyond a very limited period, the pollen of the parent species may be made to fertilize them, or their pollen to fertilize the parent; but in either case the new offspring gradually merges into the original species. Thus nature has wisely set a limit to the intermingling of species, by which they are preserved from ultimately running into confusion and disorder. The cause of sterility in hybrids is unknown; for, in general, there is no perceptible difference between the perfection and healthiness of their organs and those of the parent species.

282. *In an economical point of view*, hybridism is of great value to man. By a knowledge of its principles, he has been enabled to modify the characters of natural species, so as to adapt them to his special purposes, and thus have arisen most of those beautiful sorts and varieties of blossom which now adorn the flower-garden. So, also, by crossing varieties of the same species, our grains, fruits, and kitchen vegetables have been brought to a high state of perfection. The size of one species has been assiduously amalgamated with the durability of another, the beauty of a third with the flavour or odour of a fourth, and so on with other qualities, till we have now as many perfect vegetables as it seems possible to produce. The principles of hybridism will yet be more extensively applied; and it is not too much to expect that the perfection of our field and forest produce will yet rival that of our orchards and gardens.

GEOGRAPHICAL DISTRIBUTION OF PLANTS.

283. *The geographical distribution of plants* is influenced by conditions of soil, heat, moisture, light, altitude of situation, and various other causes; for, did they flourish independently of these conditions, then there were no reason why the vegetation of one part of the globe should differ from that of another. We know, however, that the flowers, shrubs, and trees which adorn the plains of India are not the same with those which clothe the valleys of Britain; and that these, again, are totally different from the scanty vegetation of Iceland or Spitzbergen. Each order is, nevertheless, perfectly adapted to the conditions under which it exists, and finds in its *habitat*, or native situation, all the elements which administer to its growth and perfection. A knowledge of these conditions, and of the various vegetable tribes which flourish under them, constitutes the subject of botanical geography.

299. Value to horticulturalists.
300. Examples of hybridism.
301. What of the geographical distribution of plants?

284. *The influence of soil, climate, &c. upon vegetable life* is very obvious; but the manner in which it operates is but imperfectly known. The same elements enter into the composition of the vegetation of the tropics as those which form the vegetation of temperate regions; the same organs, tissues, modes of growth, and inflorescence, are observable; and yet, without the external conditions above enumerated, a plant which has been transferred from the one region to the other will speedily languish and die. Even one which flourishes under the influence of the sea-breeze, if removed far inland, will perish; and no art can retain in healthy perfection a native of the mountain which has been transplanted to the warm and humid valley.

285. *Certain plants, like animals, may, however, be acclimatized;* that is, may be made to grow and propagate their kind in a region in which they do not naturally occur. Many of our cultivated and most useful plants are of this kind; as, for example, the potato. This plant, which is a native of tropical America, flourishes luxuriously, and is of the highest utility, in northern Europe; but this it does by a special adaptation. In South America, the warm climate enables it to propagate by the seed; hence in that region its tubers are small and insignificant; but in Europe, where the climate is unfavourable to the production of the plant from seed, it propagates by the tubers, which are consequently enlarged, so as to contain a store of nutriment for

302. Influence of climate upon vegetable life.
303. What of acclimation?
304. Illustrations of acclimation.