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# VEGETABLE PHYSIOLOGY.

## GENERAL ECONOMY OF VEGETATION.

### NATURE AND FUNCTIONS OF PLANTS.

1. Vegetable Physiology is that department of natural science which explains the organization and vital functions of plants.

2. *Plants, animals, and minerals*, are all formed by the chemical combination of certain elements. In minerals these elements combine by the force of chemical affinity only, but in plants and animals they are held in combination by vital action.

3. *Vitality* enables plants and animals to absorb and assimilate food, consisting of the elements necessary for their increase, and also to reproduce beings of their own kind, by means of certain organs: hence they are said to be *organized*, and the substances of which they are composed are known by the general name of *organic matter*. Minerals not possessing vitality have no organs, and consist only of *inorganic matter*

4. *Animals* feed partly on other animals, and partly on plants; and plants feed partly on organic matter when decomposed, and partly on inorganic. Thus minerals, by the beautiful economy of nature, contribute towards the support of animals through the medium of plants.

5. *The elements* of which organized bodies are composed, separate or decompose as soon as life has fled,

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1. Define vegetable physiology.
2. Difference between the combination of elements.
3. Modifications resulting from vitality.
4. The food of animals and plants, respectively.
5. What brings organic matter under the laws of chemical affinity?

being attracted to other bodies by the force of chemical affinity.

6. *The simplest forms of life* are observable in certain plants and animals, whose economy is limited to the absorption and assimilation of nutriment, and the power o. reproduction; and the difference between these inferior plants and animals is so trifling, that in them the animal and vegetable kingdoms seem to pass into each other. Thus, certain tribes of zoophytes, and some kinds of algæ, or sea-weed, are so very nearly allied both in appearance and habits, that they can scarcely be distinguished from each other scientifically; and, indeed, the same object has been occasionally classed as a plant by one naturalist, and as an animal by another.

7. *The scientific differences between plants and animals* are difficult to define, when they are to be applied to all plants and to all animals. Few plants possess the power of locomotion; but the aquatic plant called the fresh-water sailor detaches itself from the mud in which it grows originally, and rises to the surface of the water to expand its flowers. Plants are propagated by division, which most animals are not; but the polypes of the coral reef grow united like the buds of a plant clustering round a common stem from which they receive their nutriment, and, when separated, become each perfect individuals. Plants are said to have no stomach; but the lobe-like leaves of Venus's fly-trap possess the power of digesting the flies they catch; and though plants are said to be without feeling, the leaves of the sensitive plant shrink from the slightest touch. In like manner the pith of young trees and shrubs has been compared to the spinal marrow of animals; the upward current of the sap in spring, and its descent in summer or autumn, to the circulation of the blood; and the exhalation of oxygen and absorption of carbonic acid gas in the leaves, to respiration; but beyond a faint analogy there is nothing like identity between the respective func-

6. What are the simplest forms of life?
7. Is the line of demarcation between plants and animals distinct?
8. Wherein is the analogy supposed to approach identity?



tions of plants and animals. Indeed, all the vital functions of plants are performed in a manner different from those of animals; the instances of locomotion, sensitiveness, and power of digestion in plants, being very rare and imperfect, while the power of propagating by division in animals is equally so.

8. ***Plants derive their food*** partly from the soil, and partly from the air; and whatever they take must either be reduced to a liquid, or to a gaseous state. The elements of which plants are composed are, Carbon, Oxygen, Hydrogen, and Nitrogen. Of these, Carbon, which is a solid substance, is the principal; and, as it is insoluble in water, it must be combined with oxygen, so as to form *carbonic acid gas*, before it can be taken up by plants. Oxygen is the next in abundance, and it is absorbed principally when combined with nitrogen, in the form of atmospheric air. Hydrogen is not found in a free state in the atmosphere, and therefore it can only be taken up by plants when combined with oxygen, in the form of water, or with nitrogen, as ammonia, in which last form it exists in animal manure. Nitrogen, though found in very small quantities in plants, is a most important element, as it forms the principal ingredient in the *gluten*, which is the most nutritive part of corn and other seeds, and which is essential to the germination and first nourishment of young seedling plants. Nitrogen also appears to be a principal agent in the production of colour in leaves and flowers, especially when they first expand.

9. *As oxygen is imbibed by plants in combination with all the other elements of which they are composed,* it is not surprising that the plant takes up more of this gas than it requires; and, consequently, it has been furnished with a remarkable apparatus in the leaves, to enable it to decompose the carbonic acid, and other gases which it has absorbed, and to part with the superfluous oxygen. Plants are

9. Repeat the illustrations, and the inference best authorized.
10. Source of the food of plants, and the form or state necessary.
11. What of carbon,—of oxygen,—of hydrogen?
12. Where do they obtain hydrogen and nitrogen?

thus found to improve the air by the removal of carbonic acid, which is injurious to animal life, and by the restoration of oxygen, which is favourable to it; and so to maintain a necessary equilibrium in the atmosphere, as animals are continually absorbing oxygen, and giving out carbonic acid. In hot swampy countries, however, where vegetation is extremely rapid, and the soil surcharged with decaying vegetable matter, plants absorb more carbonic acid than they want, and give out the superfluity through their leaves; and hence, warm moist climates, such as those of some of the West India islands, though extremely favourable to vegetation, are equally injurious to human life.

10. *Light being essential to the decomposition of carbonic acid gas in the leaves,* oxygen is not exhaled by plants during the night; but, on the contrary, a small quantity of carbonic acid gas escapes, and oxygen is absorbed. These processes have been called the respiration of plants; but they are very different from the respiration of animals, the first being mechanical, and the second chemical, and both totally unconnected with the assimilation of food. When the soil abounds in carbonic acid gas and in moisture, the roots of a plant must continue constantly absorbing that moisture mixed with the carbonic acid; and this carbonic acid rising to the leaves, escapes in its original state when there is no light to decompose it. The absorption of oxygen is a chemical process, which appears to go on whenever the process of assimilation has ceased—in dead plants as well as in living ones. When leaves have ceased to act in decomposing carbonic acid, and assimilating or fixing the carbon in autumn, oxygen is absorbed so rapidly as to change their colour to some shade of red; fruit, when fully swelled, ceases to assimilate carbon, and becomes intensely acid by the absorption of oxygen; and, finally, the decay

13. What improvement of the air results from the leaves of plants?
14. What of hot swampy countries?
15. How are plants affected by the presence or absence of light?
16. Describe the mechanical and chemical process, which has been called the respiration of plants.
17. What occasions the red colour of leaves in autumn?
18. What hastens the decay of vegetable matter?



of all vegetable texture is hastened by the absorption of the same element. Thus, as the assimilation of carbon ceases during the night, oxygen is absorbed at that period in quantities that vary according to the nature of the plant; those plants which have acid, or highly-flavoured juices, absorbing most. Thus, Liebig tells us that the tasteless leaves of the American aloe, if kept in the dark twenty-four hours, absorb only 0.3 of their volume of oxygen in that time; while the leaves of the spruce fir, which contain volatile and resinous oils, absorb ten times, those of the common oak, which abound in tannin, fourteen times, and those of the balsam poplar, twenty-one times as much. The chemical action of oxygen on vegetation is strikingly exemplified in the leaves of a species of navel-wort, which are acid in the morning, tasteless at noon, and bitter at night. The acid is caused by the accumulation of oxygen during the night, the insipidity by the mixture of the oxygen with hydrogen, and the bitter flavour by an excess of hydrogen.

11. *Plants are of important service in the general economy of nature,* as well as of direct advantage to the arts and sciences. The quantity of carbonic acid which they are continually absorbing from the atmosphere during the day, serves to purify it from the immense quantity of carbon continually disengaged from the lungs of human beings and the lower animals, and from the combustion of fuel; while the oxygen with which the carbon was combined, is restored, to be again employed. Plants also act as the medium through which inorganic matter is made to contribute to the support of animal life; while they invest the landscape at once with beauty and amenity, by the variety of their hues and the shelter of their foliage.

## DEVELOPMENT AND GROWTH OF PLANTS, AS DEPENDENT ON AIR, HEAT, MOISTURE, LIGHT, AND SOIL.

12. *The development of vegetable life* depends upon the

19. Differences in absorbing oxygen, and effects.
20. Uses of plants in the economy of nature.
21. Upon what agents is vegetable life dependent?

concurrence of certain agents, the principal of which are—*heat, air, moisture, light,* and *soil.*

13. *No seed can germinate* without the concurrence of the three agents of heat, air, and moisture; but in the *growth* of plants, the agency of soil and light is also necessary.

14. *Every perfect seed contains the germ or embryo of a new plant* of the same kind as the parent, and a portion of concentrated carbon and nitrogen, in the form of starch and gluten, laid up to serve as nutriment for the young plant, till its organs are sufficiently developed to enable it to seek food for itself. The seed is generally enveloped in a hardened case, in order to preserve it in an inert state as long as may be necessary.

15. *As soon as a seed is put into the ground,* it is acted upon by the influence of heat and moisture, which distend its particles, and make them burst the integument that envelopes them. The agency of the air is next required to combine with the store of nutriment laid up in the seed, and to fit it for the purpose of vegetation.

16. *The first organ that expands* in the embryo of a young plant is the root; and nature has provided a small opening in the covering of a seed, towards which the point of the root is always turned, in order that it may be protruded without injuring its soft and delicate texture. The root takes up water and air, and transmits the liquid thus formed to the seed leaves, in which it is exposed to the influence of light.

17. *The nutritive substances laid up in the seed* become quite changed during the process of germination. The starch, which is insoluble in water, is rendered soluble by the action of a peculiar substance called *diastase,* derived from the gluten. This substance has so powerful an effect upon the starch as to render it instantly soluble in the sap, and thus the nutriment is gradually prepared for the use of

22. What of germination and growth?
23. Name the elements of every perfect seed, and their use.
24. Effects of heat and moisture upon seed.
25. What is peculiar in reference to the root?
26. Describe the changes during germination.



the infant plant. As the sap ascends it becomes sweet; the starch is changed into sugar, and this sugar, again, into woody fibre as the tip of the plant emerges into light. When the store of starch and gluten has been exhausted, the plant is able to live by its own assimilating powers, at the expense of the air and the soil.

18. *Heat,* though essential to germination, is injurious, unless it be combined with moisture. A high degree of dry heat will parch seeds, and destroy their vitality; and hence, when they are to be kept for food, it is not unusual to dry them in an oven, to prevent them from germinating. When combined with moisture, a very high temperature is not injurious to vegetation; and, indeed, some kinds of moss have been found growing near hot springs in Cochin China, where they must have vegetated in a heat equal to 186 degrees; on the other hand, in cold climates, mosses, some kinds of grass, and chickweed, are found to vegetate at 35 degrees, or even only just above the freezing point. Warmth is not only necessary for the germination of the seed, but also for the growth and after development of the plant. The sap will not rise without a certain degree of heat; and it is well known that frost stops its current. Cold will also check the development of the flowers and fruit, and even of the leaves, and will prevent the full flavour being attained by the fruit. The secretions of plants are diminished by cold. The fruit of the walnut and the beech produce oil in the south of Europe, which it will not do in Britain; and the leaves of the mulberry grown in this country will not afford the same quantity of caoutchouc to the silkworm as in France and Italy.

19. *Moisture* must be combined with heat and air to render it useful to vegetation. An excess of moisture without heat, and combined with air, induces decay in seeds, instead of exciting them to germinate; and an excess of moisture is injurious even to growing plants, as it destroys the delicate tissue of the spongioles of their roots. When trees

27. Necessary union of moisture with heat.
28. What of the importance of heat to growth and secretion?
29. What is the effect of moisture, uncombined with heat and air?

are grown in situations where they have abundance of heat and moisture, but where the roots are beyond the reach of air, they have a tendency to produce leaves instead of fruit and seeds, and all their secretions are weakened. On the other hand, too little moisture prevents the leaves and fruit from attaining their proper size and form. A sudden deprivation of moisture causes the leaves to droop and the fruit to fall off.

20. *Air* is essential both to the germination of the seed and the development of the plant. Without oxygen from the atmosphere, the carbon laid up in the seed cannot be made available for the use of the infant plant, as carbon in its concentrated state is insoluble in water, and requires to be combined with oxygen to convert it into carbonic acid gas, before it can be absorbed by the vessels. In like manner, air is essential through all the processes of vegetation; no wood can be formed, no seed ripened, and no secretions produced, without abundance of carbon; and this cannot enter the plant, even from the soil, without a constant supply of oxygen from the air. The greater part of the carbon in plants is indeed derived directly from the air by the leaves, in the shape of carbonic acid gas—a minute quantity of which is always found in combination with the atmosphere.

21. *Light* is not required for the germination of seeds, but it is essential to the development of plants, as it occasions the decomposition of the carbonic acid contained in the vessels of all the parts exposed to its influence; without which the plant could not assimilate the carbon to its own use. Colour also appears to depend partly on light. Plants grown in darkness are most deficient in colours which contain blue. The leaves and other parts, which should be green, are frequently reddish, from the retention of oxygen, or yellowish, from the superabundance of nitrogen, while the flowers and fruit are whitish. Frequently, the whole plant is whitish, in which case it is said to be *etiolated*, or blanched.

30. Importance of air to vegetation, and why?
31. Uses of light, and illustrations.



22. *The soil* serves not only as a bed for the plants to grow in, but also contributes to their nourishment. In addition to the elements of which they are principally composed, there is always found in their substance a small quantity of inorganic matter, which differs according to the nature of the plant, and which appears to be derived solely from the soil. The proportion which this matter bears to the whole will be found by burning part of the plant in the open air; when the inorganic matter, being indestructible by fire, will be left in the form of ashes. Soils are of various kinds, and they are produced principally by pulverized particles of rocks, being disengaged by the action of heat, air, and water, and mixed with decaying animal and vegetable substances.

23. *There are four primitive earths*, called *clay*, *sand*, *lime*, and *magnesia;* the first three of which are found more or less in almost every soil, and generally with only a very small proportion of the latter. Clay, which is also called *alumina*, or *argillaceous earth*, or *earth of alum*, predominates in some soils, and these are generally unfertile; as the particles of clay are too adhesive to allow the free passage of either air or water to the roots of plants. A soil of this kind also offers obstacles to the expansion of fibrous roots; and when it admits water, it retains it so long as to be injurious. Sand, which is also called *silex*, *silica*, or *siliceous earth*, consists, on the other hand, of particles which have generally too little adhesion to each other; and it is injurious to plants, partly from its incapability of retaining sufficient water for their nourishment, and partly because it admits too much solar heat to their roots. When the particles of sand adhere to each other, they form sandstone, or some other mineral substance equally impenetrable by roots. Lime is never found in a pure state in nature, but always combined with some acid. The common carbonate of lime or limestone is of no use

32. Uses of the soil, and what of inorganic matter?
33. Name the four primitive earths.
34. Define clay, its nature and effects in soil.
35. What is sand in soils?
36. Nature of the combinations of lime in soils, and magnesia?

in vegetation till it has been burned—that is, till the carbonic acid, water, and other matter it may contain, have been driven off by heat. In this state it is called caustic lime, and is used as a manure, as it has a great affinity for carbonic acid, which it is continually drawing into the soil from the atmosphere or other sources. Chalk, or the earthy carbonate of lime, is well adapted for vegetation, but it is generally cold, as, from its whiteness, it reflects the solar rays instead of absorbing them. Magnesia is very similar to lime, but is less abundant. It generally occurs in combination with lime, in what is called magnesian limestone. Notwithstanding the whiteness of chalk, calcareous soils—that is, soils containing some form of lime—are generally black, from the quantity of vegetable matter which they contain in proportion to the depth of the soil. All soils containing a great proportion of decayed vegetable matter are black; and black soils, though generally warm, from the power they possess of absorbing solar heat, are seldom productive, unless they be dry. Thus, black peat, or bog earth, which is moist, is unproductive, while heath mould, mixed with sand, which is dry, is very useful for many kinds of crops. The reason is, that decayed vegetable matter, or *humus,* is insoluble in water, and consequently cannot be taken up by plants until the carbon it contains is combined with oxygen, so as to form carbonic acid gas, which it can only do when the humus is kept sufficiently dry to allow of its particles being exposed to the free action of the air.

24. *It must be observed, that no soil consists of any one of the primitive earths alone,* and that most soils contain all of them combined in different proportions, and mixed with other ingredients. These are saline particles of various kinds, potash, soda, and other alkalies, iron, and several other minerals, in combination with the different acids—all of which are designated, when speaking of the food of plants, by the general name of *inorganic matter.*

25. *Plants require different kinds of inorganic matter,*

37. What is said of black soils, their variety?
38. Name the inorganic matter of soils, other than earths.



*according to their nature,* and appear to possess the power of selection, as they only take the kind they need, though it may form but a very small portion of the soil in which they grow. Thus, it is evident that any particular crop must in time exhaust the soil in which it grows of the requisite inorganic matters, unless they should be renewed by the addition of what are called mineral manures; and it is also clear that crops requiring another kind of earth, may succeed in the same soil, after it has become unproductive for the first kind of crop. This, according to modern doctrines, explains the necessity which is known to exist for what is called *the rotation of crops*—that is, for letting crops of a different nature succeed each other in fields and gardens. The necessity for this rotation was supposed by De Candolle and others to arise from plants poisoning the soil with the excrementitious matter which they were supposed to eject by their roots; but while this hypothesis was believed, it appeared difficult to account for the well-known fact, that the same crops may be grown perfectly well in any soil for an indefinite number of years, provided that soil be frequently and properly manured—that is, supplied afresh with the ingredients of which it has been exhausted by the plants.

26. *Nature, when unassisted, invariably changes the crops of plants* whenever occasion for such a change occurs; and if a forest of North America should be accidentally burned down, trees of quite a different nature are sure to spring up in the room of those that have been destroyed. These changes are effected in various ways. Many seeds are furnished with downy wings, on which the wind bears them far away from their parent plant; and other seeds burst from their seed-pods with such elasticity, as to be scattered to a considerable distance. Suckers from under-ground stems, and runners of various kinds, are other means by which plants are enabled to obtain nourishment from fresh

39. Is there any thing like elective affinity to soils of a peculiar kind on the part of plants?
40. What of the necessity of rotation of crops?
41. How are the changes of crops of plants to be accounted for occurring spontaneously?

soils when they have exhausted that in which they originally grew; and nature has afforded similar powers to even the largest forest trees, by enabling them to elongate their roots to any extent that may be required.

27. *Plants do discharge matter from their roots*, but it is generally of the same nature as the peculiar secretions of the plant; as, for example, the matter exuded by the roots of the poppy has the properties of opium, that from the oak tannin, &c. The excretory matter is thus evidently part of the elaborated or most perfect kind of sap.

### TERM OF VEGETABLE EXISTENCE.

28. *The longevity of plants* differs according to their nature, and the circumstances in which they are placed.

29. *Herbaceous plants*, the stems of which are succulent, and full of juice, are divided into three kinds, according to the term of their existence; namely, *annuals*, which grow only one season, and die as soon as they have ripened their seeds; *biennials*, which generally last only two years; and *perennials*, which last several years. To these, practical horticulturists sometimes add a fourth kind, consisting of such as last three or four years, but no longer, and which have no distinctive name, though they are generally classed with biennials.

30. *Trees and shrubs*, which have *ligneous*, or woody stems, are destined to remain undecayed for years. Shrubs are those ligneous plants which have several stems springing from the same root, all nearly of the same thickness. They seldom last above thirty or forty years, and frequently not half that time; but trees which have only one stem or trunk proceeding from the root to a considerable height before it divides into branches, generally endure for a long period of time—in several instances even for centuries.

31. *The length of time which trees live* depends in a great measure on the situations in which they grow. If a tree which is a native of mountains be placed in a valley,

42. What discharge proceeds from the roots of plants?
43. What of the longevity of herbs, trees, and shrubs?
44. What circumstances vary the longevity of trees?



it grows more rapidly, but the term of its existence is shortened, and its timber becomes softer and of less value. In like manner, if the tree of a valley be grown on a mountain, the term of its existence is lengthened, and its trunk, though of slow growth and small dimensions, produces timber remarkable for its toughness and durability; as, for example, the Highland oak.

32. *The age of trees was formerly calculated* by their diameter, or by the number of their concentric circles; but both these modes are found to be fallacious. According to the first it was supposed that if a tree attained the diameter of a foot in fifty years, fifty years should be counted for every foot it measured in diameter; and thus it was supposed that the great baobab tree, found by Adanson on the banks of the Senegal, which measured nearly thirty feet in diameter, must have been about six thousand years old, or coeval with the world itself. It is now found, however, that the baobab, like all soft-wooded trees, grows rapidly, and attains an enormous diameter in less than a hundred years. The mode of counting by concentric circles only applies to exogenous trees, and even with them it is very uncertain. A warm spring, which sets the sap early in motion, followed by weather cold enough to check vegetation, will give the appearance of two layers in one year, as the recommencement of vegetation will have the same appearance as a new layer in spring. In many trees, such as the oak, for example, a second growth often takes place after midsummer; so that even a third layer is occasionally formed in the course of six months. On the other hand, a moist warm winter, by keeping the tree growing the whole year without any check to vegetation, will give the appearance of only one layer to the growth of two years. Notwithstanding these anomalies, practical men find counting the concentric circles of a tree the best mode which has yet been discovered of ascertaining its age, as in ordinary cases only one growth is made in the course of a year.

45. What modes of ascertaining the age of trees are cited?

33. *The natural decay and death of plants* appear to follow the same laws as the natural decay and death of animals. When a tree approaches the term of its existence, the sap flows more feebly through its vessels, and it is no longer propelled through every part. As this takes place, the parts no longer visited by the sap die; and as soon as life has fled, the opposition principle of chemical affinity begins to act, and the various elements that composed the plant fly off, to combine with other elements, so as to form new substances. This is the natural process which takes place invariably with every organized being; the fall of the leaf, and the dropping of the ripe fruit, are but the death of both when fully matured; and in the like manner death is followed in both instances by its natural attendant, decomposition. [Death, however, in the case of the family of man, is ascribed in the Scriptures to Divine appointment, as the consequence of sin. A large majority of our race die in infancy, instead of perishing by this "natural process" at maturity. So that the analogy must not be understood to apply to man among the animals whose decay and death follow the same laws as in the case of the leaf or an apple.]

## SIMPLE OR ELEMENTARY ORGANS.

34. THE ORGANS with which both plants and animals are gifted to enable them to carry on the functions of life, are of two kinds; namely, *simple organs*, such as the flesh of animals, and the cellular tissue of plants; and *compound organs*, such as the leaves of plants, and the limbs of animals—the latter always consisting of certain arrangements or combinations of the former.

35. *The principal substance* of which plants are composed is known by the general name of *tissue;* but of this there are three distinct kinds, distinguished as *cellular*,

46. Is there any analogy between the decay and death of plants and animals?
47. How are the organs of plants and animals divided?
48. What division is made of vegetable tissues?



*woody*, and *vascular*, which have been compared to the flesh, bones, and veins of animals. These principal tissues are occasionally subdivided into varieties on account of some minor distinctions, such as vascular tissue, which may be either vascular proper, pitted, or lactiferous.

### CELLULAR TISSUE.

36. *Cellular tissue* is the fleshy or succulent part of plants, of which familiar examples may be given in the pulp of leaves and fruits. It consists of a great number of cells of irregular shape, which adhere together, sometimes quite loosely, as in the pulp of an over-ripe orange; and at other times—as, for example, in the cuticle or outer skin—so closely, as to seem to form a homogeneous mass, unless examined by a powerful microscope. Formerly, indeed, it was supposed that an extremely thin membrane was spread over the external surface of some plants; but it is now found that what was supposed an extraneous membrane, is in fact only a more condensed form of cellular tissue.

37. *Each cell* of cellular tissue consists of a small bag or bladder, filled apparently with liquid; but intermixed with this liquid, which consists of hydrogen and oxygen nearly in the same proportions as in water, there are some grains of starch and some of colouring matter, surrounded by a few particles of gluten. The starch, which has been compared to the fat of animals, consists principally of carbon; and the gluten of nitrogen. Occasionally, small crystals are found in the vesicles of cellular tissue, which, when they are needle-shaped, are called *rapides;* sometimes, however, they are of a rhomboid, at other times of a prismatic form. They consist of inorganic matter, generally of some acid and its base, which, from the feeble state of the assimilating powers, have united and crystallized, instead of passing in a separate state through the vessels of the plant, to assimilate with the peculiar secretions. Some cells are entirely filled with these crystals,

49. Describe the cellular, with examples.
50. What are the nature and contents of these cells?