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?

and others are entirely without them. The cells of the epidermis, instead of liquid, contain only air.

38. *The cells of cellular tissue vary very much both in size and shape.* They generally, however, present the appearance of a honeycomb when sections are cut of the pulp of the leaves, pith, or fruit (see fig. 1); but in sections of the bark and sap-wood, they take a parallelogram form, and resemble the bricks of a wall (see fig. 2). The cells are generally small when they are first formed, but they increase

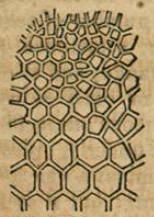

Fig. 1.—Cellular Tissue in a Leaf.

Fig. 2.—Muriform Cellular Tissue in Wood or Bark.

in size as they become older. Thus, in the cellular tissue of a leaf, the cells are at first very small, but as fresh cells are formed close to the veins, the cells towards the margin of the leaf dilate; and a similar process takes place in every part of the plant, the newly formed tissue always consisting of cellules, which enlarge as they get older.

39. *In the pulp of leaves and fruit*, and in the cellular tissue of the bark, there are frequently cavities found among the cells, which are of several kinds. Those called *receptacles of secretion* are formed for the reception of the oils and other fluids secreted by plants; as, for example, the fragrant oil in the myrtle and the orange, and the turpentine in the Pistachia and in the pine and fir tribe. Other similar cavities, called *air cells*, contain oxygen nearly in a pure state; and others, which are called *intercellular passages*, are generally filled with watery fluid, and communi-

51. Describe the varieties of the tissue.
52. Are there other cavities, and what do they contain?

cates with the open air by means of pores in the epidermis. All these cavities have no distinct membrane to enclose them, but are surrounded by what may be called a wall of small cells, which form part of the cellular tissue. The shape and size of these cavities vary exceedingly; the receptacles of secretion, and the air cells, are generally larger than the common cells, but the intercellular passages in very dry plants are so small as to be scarcely perceptible; though in succulent plants—as, for example, in the stem of the garden Nasturtium—they are nearly as large as the cells.

40. *Cellular tissue readily decays* when the parts composed of it fall from the tree. The carbon it contains is liberated so soon as the vital force by which it was retained has fled, and escapes with the oxygen in the form of carbonic acid gas; whilst the hydrogen, which then forms its principal remaining element, attracts fresh oxygen from the atmosphere, and, becoming thus changed into water, rapidly melts away, leaving the inorganic portion to mix with the soil. In leaves, the pulpy parts disappear first, leaving behind the outer cuticle and the nerves of veins, which are of firmer texture; the latter, indeed, being composed principally of woody fibre, the tubes of which have been filled with earthy matter during the process of vegetation, decay very slowly. A beautiful preparation may be made by soaking, or macerating, as it is called, leaves in shallow stagnant water, so as to leave them perpetually exposed to the influence of the air; thus treated, the cellular tissue will soon disappear, and the veins will present the appearance of the finest lace.

41. *Those parts of a plant which nature seems to have intended not to be of long duration*, such as the fleshy parts of the leaves, the flowers, and the fruit, are composed entirely of cellular tissue of very loose texture. In the stones of fruit, however, which are also composed of cellular tissue, a portion of earthy matter is deposited, which partially

53. What tissue of plants first decay? Examples.
54. How has nature provided for shorter or longer duration in certain parts of plants, though both alike cellular and perishable?

lines the cells, and gives them a temporary firmness, without destroying their facility of decay; so that the seeds contained in them may be preserved as long as they are kept in a dry state, and yet liberated so soon as they are placed in a situation favourable for germination.

WOODY TISSUE.

42. *Woody tissue* consists of bundles of extremely fine cylindrical cells, tapering at both ends, and of great length

Fig. 3.—Woody Tissue.

and toughness (see fig. 3). The bundles have so much the appearance of fibres, that their true nature was not suspected by the older botanists; and it was supposed that they retained their fibrous appearance even when subjected to the most minute division. It is now found, however, that the fibres of woody tissue cannot be divided beyond a certain point, and that, though they may be made so small as to take seven or eight of them to equal the thickness of a fine hair, each of these exceedingly slender fibres is in fact a hollow tube tapering at both ends, and adhering to other hollow tubes of a similar nature, as shown in fig. 4.

Fig. 4.—Single Fibre of Woody Tissue

The tubes of woody fibre, when young, serve as channels for the passage of the ascending sap; but afterwards they become filled with particles of inorganic matter, which give solidity and durability to the wood. Woody fibre is found mixed with cellular tissue in the wood and inner bark of trees; it also forms part of the veins or nerves of leaves; and in general is found in all organs which require strength,

55. Describe the woody tissue of plants, and its qualities.

toughness, and durability. It resists decay longer than any other kind of vegetable tissue.

VASCULAR TISSUE.

43. *Vascular tissue* has been divided by modern botanists into three varieties; namely, *vascular proper*, *pitted*, and *lactiferous*. Vascular tissue, properly so called, consists of cylindrical cells of great delicacy and thinness, called *spiral vessels* and *ducts*. *Spiral vessels* consist of hair-like tubes coiled round and round in a spiral manner, and enclosed in tubes of transparent membrane. They are of a light elastic nature, and though coiled up naturally like a cork-screw (see fig. 5), they may be unrolled to a

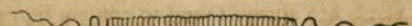

Fig. 5.—Spiral Vessel.

considerable extent. If a leaf of the spider wort (*Tradescantia*), or of any kind of bulb, be doubled down first on one side, and then on the other, so as to break through the outer skin on both sides, and if the two pieces of the leaf be then carefully and gently drawn asunder, the transparent membrane will break, and the spiral vessels will unrol, so as to appear, when seen with the naked eye, like fine hairs between the two portions of the leaf. The stalk of a strawberry leaf, a shoot of the dogwood, and the young stems and leaves of many other plants, will show the great extent to which their spiral vessels will unrol, if treated in a similar manner; but in many plants these vessels are too fine to be seen without a microscope, or too delicate to bear unrolling. Spiral vessels prevail in leaves and flowers, and are found, though more sparingly, in the young green wood of trees and shrubs; but never in the old solid wood, and very rarely in the roots, or in the bark. They are very few and small in coniferous trees; but they are abundant in palms and their allies. In ferns and the club mosses they

56. How is the vascular tissue divided?
57. What is said of spiral vessels?

occur occasionally; but the other cryptogamous plants are entirely without them. These vessels are sometimes called *air vessels*, because their slender spiral tubes are always found filled with a kind of air, which contains seven or eight times more oxygen than the common air we breathe. *Ducts* are cylindrical tubes closely resembling those which enclose the air vessels; only the spiral vessels they contain appear to have been broken into rings, or short corkscrew-like curves, which sometimes cross each other in a reticulated manner. These rings and curves are, however, quite different from the true spiral vessels, as they have no power of unrolling, and appear only intended to keep the slender membrane which forms the duct distended. Similar rings are found in the windpipe of animals, which appear also only intended to keep that membrane distended. The ducts in plants are always found to contain liquid.

44. *Pitted tissue*, sometimes called *dotted ducts*, or *vasiform tissue*, consists of tubes which, when held up to the light, appear full of holes, from the numerous dots in the lining of their sides. The mouths of these tubes are very conspicuous in the wood of the rattan when cut across; they are also to be seen in sections of the oak and the vine; and, indeed, in most other kinds of wood, as well as in the stems of herbaceous plants. Being the channels through which the ascending sap is conveyed, the dotted ducts are larger than the vessels of the other tissues, and are distinctly visible in many kinds of wood, even when dry. Modern botanists consider them as belonging to cellular tissue, and as consisting only of elongated cells placed end to end, and opening into each other so as to form a kind of tube. The dots are supposed to be formed by deposition of earthy matter, like that in the cellular tissue which forms the stones of fruits, and which botanists call *sclerogen*.

45. *Lactiferous tissue*, which is the same as the proper vessels of the older botanists, consists of tubes, which are

58. Describe the spiral ducts.
59. What of the pitted tissue, with examples?
60. What is the nature and use of the lactiferous tissue?

distinguished from all other kinds of tissue by being branched. They are filled with a mucilaginous fluid called the *latex*, which is, in fact, the descending sap, and is full of numerous small specks, like that which is the germ of the future chicken in the egg of a hen. These specks are always in motion while they remain in the vessels of the latex, and whenever they are deposited, they expand into cells of different kinds of tissue. From the latex, also, is formed gum, sugar, tannin, or other secretions, according to the nature of the plant. The vessels of the latex are found on the under sides of leaves, and within the inner bark, which they may be said to line: hence the peculiar secretions of a tree are generally strongest in the bark, and what are not deposited there, are in most cases carried down to the root.

46. *Most kinds of tissue* may be traced in all the compound organs of plants, though in different proportions, except the vessels of the latex, which are only found in the under part of the leaves, and lining the inner surface of the liber, or inner bark.

COMPOUND ORGANS, AND THEIR FUNCTIONS.

47. The compound organs of plants are composed of several of the simple ones; as, for example, a leaf has woody and vascular tissue in its veins, and cellular tissue in its pulpy part; and in like manner, these elementary organs are found in the stem, flower, fruit, and, in fact, in every part of the plant. The compound organs are divided into three kinds; namely, the *general organs*, which are common to every part of a plant, such as the *epidermis*, or skin, and the hairs; *the organs of nutrition*, through which the plant takes and digests its food, such as the root, stem, and leaves; and *the organs of reproduction*, which are the flowers, fruit, and seeds.

61. How are the compound organs of plants divided?