springs, *d* is the foramen, and *e* the hilum. B shows the embyro picked out of the seed with the cotyledons (*a*) partly divided, and the radicle (*b*) before it begins to elongate. Fig. 74 at A shows the outside of a seed of the red currant, with the chalaza at *a*, the raphe at *b*, and the hilum at *c*. B is the same seed split in two, showing the section of the raphe (*b*), the large albumen (*d*), with the little embryo at the base, with its root pointing towards the hilum (*c*), the foramen being just above it.

167. *In every ripe seed* a quantity of nearly pure carbon and a small quantity of gluten are laid up for the nourishment of the future plant, either in the albumen or in the cotyledons. The latter, when not fleshy, always rise above the surface of the ground in the shape of leaves (called seed or *seminal* leaves), though their form is different from that of the true leaves. Sometimes fleshy cotyledons do the same, as in the lupine; but generally they remain in the ground, as in the horse-chestnut, the oak, and the broad bean. The cotyledons, when leafy, fall off when the true leaves expand; and when they remain in the ground, they gradually waste away, as the nourishment they contain is required by the young plant. The same thing takes place with the seeds when they are albuminous. All the plants in the same genus have seeds of the same kind as regards the position of the embryo and the albumen.

168. *The embryo of endogenous plants* is usually a solid cylindrical or roundish body, without any appearance of being divided into radicle, plumule, and cotyledons, till it begins to germinate; hence these plants are said to be *monocotyledonous*. In germinating, the single cotyledon always remains in the ground, enclosed in the testa of the seed, while the root protrudes and elongates considerably before any plumule appears. In some of the endogens, the embryo has a second or accessory cotyledon; but this is always very small and imperfect.

169. *From the structure of the embryo* the terms *dicotyledonous* and *monocotyledonous* are generally used indiscriminately for exogenous and endogenous; while *cryptogamous*, or flowerless plants, from being propagated by sporules instead of seed, are said to be *acotyledonous*; that is, without any cotyledon whatever.

177. Composition of ripe seed.
178. Describe the varieties in the structure of the embryo.

FUNCTIONS OF THE ORGANS OF REPRODUCTION.

170. THE FUNCTIONS OF THE ORGANS OF REPRODUCTION are strongly marked; for, as the production of the future plant entirely depends on the formation of the seed, more than usual means have been provided for enabling plants to lay up a stock of nutritious sap for the formation of the different parts of the flower. The proper juice, which has been matured in the leaves, passes through the peduncle to the calyx, which is generally furnished with hairs, to collect moisture from the atmosphere, and thus enable the plant to procure a sufficient quantity of nitrogen, as the starchy matter contained in the proper juice requires to be converted into sugar before it can afford nourishment to the organs of reproduction, and this sugar it deposits in the disk of the flower. This process is repeated by fresh sap constantly rising, and none returning, till at last the disk of the flower becomes so charged with sugar, that it escapes in the form of honey. In some cases this liquid honey is so abundant, as to half-fill the cup of the flower, as in the Nepaul tree rhododendron. The sugar thus deposited serves to nourish the stamens and pistils, the anthers enlarge, and their cases become filled with pollen; while, on the other hand, the ovary forms, containing within it the ovules or incipient seeds. At length the anthers burst, and the pollen falls on the stigma, which exudes a slightly glutinous fluid, to which the grains of pollen adhere, and each then sends down a delicate membrane in the shape of a tube, which passes between the cells of the style, and entering the ovary, penetrates each ovule through the foramen.

171. *The curious formation of the grains of pollen* has

179. What of the functions of these organs?
180. Describe the process of reproduction in plants.
181. Office and peculiarities of the pollen.

been already alluded to; and it will be seen, on a close examination, that the outer coat of the grain bursts when it is ripe, and that the inner coat elongates itself into the shape of a tube. The cells of the stigma are also beautifully contrived to admit the passage of these tubes, as they are long and extremely loose in texture; at the same time so moist and elastic as to be easily compressed when necessary. It is so contrived, that the minute particles contained in the grains enter slowly to the ovary, as it seems necessary that the fecundating matter should be admitted by degrees. It is also necessary that the tube should enter the foramen of the ovule, and as the ovule is not always in a proper position to receive it, it will be found to erect itself, or to turn, as the case may be, while the granules of the pollen grains are passing down the tubes. The tubes of the pollen grains do not appear till the pollen touches the stigma, and they then gradually elongate, forming fresh cellular tissue at the extremities, till they become sufficiently long to reach their destination. The formation of the new cells at the extremity of the tubes may be seen by a powerful microscope. The ovules are also fed at the same time by starchy matter absorbed from the ovary through the placenta, to which they are attached.

172. *When the seed has been fecundated by the pollen*, the petals and stamens of the flower fade, but the calyx sometimes remains attached to the ovary, in which the seeds now rapidly develope themselves, being fed with the rich sap which continues to rise through the peduncle. In most forest trees, the *pericarpium*, or covering of the seed-vessel, is dry; but in fruit trees it is fleshy. When this is the case, it is generally a part of the disk which becomes eatable. In all the British stone and kernel fruits, the eatable part is a portion of the disk which lines the tube of the calyx, and which thus forms a covering to the ovary. The epidermis of the calyx has scarcely any pores, and consequently, as the oxygen contained in the sap cannot escape, when the latter is decomposed, to deposit the carbon in the seed, this

182. How is the embryo nourished?
183. Describe the process of ripening.

part becomes intensely acid. When the seed is ripe, it ceases to require any more carbon, and this substance is deposited in the pulp, which now loses its acidity, and becomes sweet. In some fruit—as, for example, the peach—the epidermis is furnished with hairs to collect moisture from the atmosphere, and consequently this fruit abounds in juice.

173. *Some plants ripen their fruit* in a much shorter period than others; and this process is greatly facilitated by increase of temperature. In many, the seed is ripe in a few days after flowering; in the grape it takes from fifteen days to a month; in the rasp and strawberry about two months; in the horse-chestnut four; in the apple and pear five; in the beech and walnut six; in most pines about a year; and in some oaks eighteen months. The peduncle, when no longer wanted to convey nourishment, withers, and the fruit falling to the ground, begins gradually to decay; and in this process the mass of pulpy matter, abounding in carbon, attracts oxygen from the atmosphere, and thus forms a supply of carbonic acid gas admirably adapted for the nourishment of the young plant, which the return of spring raises from the seed. In fruits having a dry pericarp, the concentrated state of the carbon preserves the fallen seeds from decay, till the embryo is called into action by the warmth of spring.

GERMINATION.

174. The germination of a seed is the change of the inert, and apparently lifeless embryo, into a living plant; and this is effected by the influence of heat, air, and moisture, which both excite the vital action of the embryo, and change the albumen of the seed into food proper for its support.

175. *Seeds cannot germinate* if any one of these three agents of heat, air, and moisture, be wanting. Seeds in the bed of an Italian river, where, of course, they had abun-

184. What agencies contribute to germination of seed?
185. Effect of the absence of either of these agents.

dance of heat and moisture, were known to lie there more than fifty years perfectly inert, and yet to germinate as soon as they were exposed to the air, by being thrown with the mud of the river on the banks. Heat and air, without moisture, will dry seeds, and air and moisture, without heat, will rot them; but in neither case will they vegetate. Light, instead of being favourable to the development of the embryo, seems rather to retard it, and seeds are found to germinate readily in darkness.

176. *When the seed of an exogenous plant is put into the ground,* so as to exclude the light, but not the air, and supplied with heat and moisture, the combined effect of these three active agents will distend the particles of which the seed is composed, till it becomes so much enlarged that the outer covering cracks, and a small portion of the embryo appears projecting through the *foramen.* The period that elapses between the time when seeds are placed in a situation favourable to their development, and the time of germination, varies considerably. For example, the common cress germinates in two days, the turnip in three, grasses in eight, hysop in a month, many pines in a year, and the hazel not until two years.

177. *When germination has taken place,* a supply of food is necessary to form new cellular tissue; and it is on this account that nourishment is laid up in the seed, as the young plant cannot obtain food either from the ground or the air till its roots and leaves be developed. It cannot, however, at first avail itself of this provision, as its vessels can only take up liquid food, and neither starch nor gluten are soluble in water. To obviate this difficulty, as soon as the particles of which the seed is composed begin to be distended by heat, the seed absorbs water, and this being decomposed by the greater attraction of the carbon contained in the seed for the oxygen of the water, carbonic acid is formed. It is supposed that this carbonic acid combines with the nitrogen in the gluten of the seed, and produces a sweet substance called *diastase;* which, combining

186. Describe the process and period of germination.
187. How is the young plant nourished?

with the remainder of the carbon, changes it into sugar. The young plant is thus furnished with all the nourishment it requires; the carbonic acid gas is dissolved in water and taken up by the spongioles, and the sugar is dissolved by the ascending sap in the sweet juice which is always found at the base of the growing part of a plant. As a considerable quantity of water is necessary to dissolve this sugar, and carry it upwards, more water is always taken up by a growing plant than is actually wanted for food; and in the same manner an extra quantity of oxygen is required to keep the carbon in a soluble state during its passage upwards.

178. *All seeds become sweet* during the process of germination, and it is in this manner that barley is changed into malt. The seed of the barley is moistened, and exposed to the influence of heated air in the kiln, till the embryo begins to grow, when its further progress is checked by putting it into the dry kiln, by which means the sweetness is retained, and malt is produced.

179. *The plant being provided with nourishment,* begins rapidly to develope itself. First, from the part projecting from the foramen, which now becomes the collar, a taproot descends, throwing out on each side a great number of short fibrous roots, each terminating in a spongiole. The *plumule,* or ascending shoot, next rises from the collar,

Fig. 75.—Germination of Dicotyledonous and Monocotyledonous Plants.

expanding its cotyledons (*a* in fig. 75) long before its other leaves unfold. The plumule generally lies concealed be-

188. What of barley and malt?
189. Describe the development of plants.

tween the cotyledons, from which situation it emerges when the cotyledons open, as shown in the common bean (fig. 76). The sap now being exposed to the air, by passing through the numerous veins of the cotyledons, becomes enriched by the evaporation of its superfluous water and oxygen, and is changed into what botanists call the *descending*, *arterial*, or *vital sap*. In this state the sap consists only of carbon and water, or, to speak more correctly, of carbon combined with oxygen and hydrogen, in the proportions in which those gases are found in water; but from this four distinct substances are formed by the wonderful alchemy of nature, which are deposited by the proper juice to meet the wants of the growing plant. These four substances are starch, sugar, gum, and lignine; all of which, though apparently so different in their natures, are composed of carbon and water; and, strange to say, almost in the same proportions.

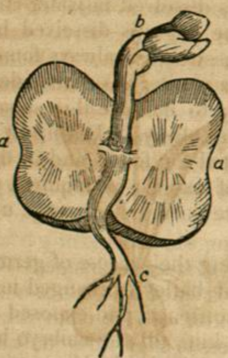

Fig. 76.—The Common Bean.

180. *Cotyledons are never found on young plants, unless these are raised from seed.* In such as are raised from bulbs, corms, and tubers, growth is merely the development of a bud. The bulb gradually wastes away as its store of albuminous matter is exhausted, and a new one forms in the axils of its leaves by its side. In a corm the same wasting away takes place, but the new corm is found above the old one, as in the crocus (see *a* in fig. 77). Tubers disappear in the same manner, but a distinct new tuber is formed by the side of the old one. Thus, if the root of the common orchis be examined while the plant is in flower, it will appear to have two tubers (see fig. 78); though, if the same plant be re-examined after the seeds have ripened, only one

190. Name the four proximate principles.
191. What of cotyledons?

tuber will be found; the old one (*a*) having wasted away—its place being supplied by the new one (*b*). The analogy

Fig. 77.—Germination of Bulbs and Corms.

Fig. 78.—Tubers of the Orchis.

between bulbs and buds is still further proved by the fact, that many plants bear bulbs in the axils of their leaves. Every bud is also a separate plant, which will grow like a bulb when put into the ground; this the gardeners call *striking by eyes*. *Budding* is on the same principle, only the bud is inserted into the sap-wood of another plant, and not into the ground.

181. *In monocotyledonous plants*, raised from seed, the radicle, when it projects from the seed, is enfolded in a covering called the *coleorhiza*, or root sheath (*c* in fig. 75). When the sheath has attained a considerable length it splits asunder, and from this opening arises the plumule (*p*), while the radicle (*r*) descends into the soil.

182. *Acotyledonous or cryptogamous plants* have no cotyledons, as the spores by which they are propagated are not seeds, but minute plants, which enlarge directly by the addition of new tissue. But of these curious forms of vegetation in another section.

FRUCTIFICATION OF FLOWERLESS PLANTS.

183. THE FRUCTIFICATION OF FLOWERLESS OR CRYPTOGAMOUS PLANTS is very remarkable, and quite different from that of flowering plants. They have neither flowers nor seeds, but are propagated by little embryo plants, called *spores*, or *sporules*.

184. *In the ferns*, or *filices*, which are the largest of the flowerless plants, little brown spots, called *sori*, may be observed on the backs of the leaves (see fig. 79). Each of

Fig. 79.—Ferns, showing the Sori on the back of the Fronds.

these is composed of a number of minute membranous capsules, termed *thecæ*, which contain the reproductive sporules. The thecæ are either sessile or pedicellate, being in the latter case surrounded by an elastic ring, which aids in bursting asunder the membrane, and dispersing the spores. Sometimes the sori originate under the epidermis of the leaf, forming minute protuberances; the portion of cuticle covering each sorus being called its *indusium*.

185. *Ferns are plants* generally consisting of a number of leaves, attached by tough fibrous petioles to a subterranean stem, the fronds being the only visible portion of the plant. In some varieties, however, the stem rises above

192. What of flowerless plants?
193. Define the italicised technicals.
194. Describe the ferns.

ground to the height of forty or fifty feet, forming the well known *tree-ferns* of New Zealand and Van Diemen's Land (see par. 85, fig. 19).

186. *The equisetaceæ*, or *horsetails*, have their thecæ on the points of the bracteated spikes, which are placed in rings round the stem (see fig. 80). In the thecæ are slen-

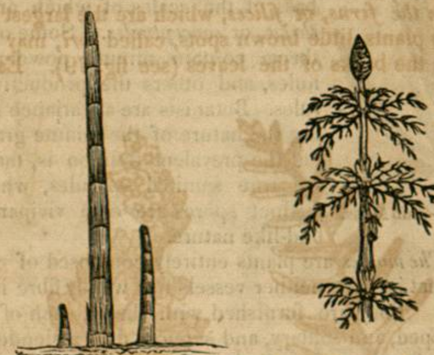

Fig. 80.—Equisetaceæ, Simple and Branched.

der elastic bodies, thickened at the end, called *elaters*, which are attached to the sporules, and at first rolled round them, but which open with a jerk, making the sporules appear to jump as if alive. The equisetaceæ are herbaceou sperennial plants, having hollow striated stems; these being either simple or branched, and jointed at intervals.

Fig. 81.—Pillwort.

187. *The marsileaceæ*, or *pillworts*, are aquatic herbs, which have ball-like receptacles at the base of their leaves (see fig. 81), containing the sporules and other minute granules supposed by some to be spores

195. What other plants are named, and their peculiarities?

in an undeveloped condition. The receptacles are always attached to leaves situated near one of the roots.

188. *The lycopodiaceæ*, or *club mosses*, which are intermediate in appearance between the true mosses and ferns, have bracteated spikes, like small fir cones, at the end of their branches (see fig. 82), at the base of the scales of which are their *thecæ*, or *conceptacles*. Some of these thecæ contain minute powdery granules, and others the productive sporules. Botanists are at variance regarding the nature of the minute granules; but the prevalent opinion is, that they are true seminal sporules, while the distinct spores are of a viviparous or bud-like nature.

Fig. 82.—Club Moss.

189. *The mosses* are plants entirely composed of cellular tissue—that is, have neither vessels nor woody fibre in their structure. They are furnished with thecæ, each of which is urn-shaped, and solitary, and supported by a slender stalk called a *seta*, which springs from a tuft of leaves called the *perichætium*. Each theca is covered by a small conical cap called the *calyptra*, or veil (see fig. 83. *a*), which is pushed off by the expansion of the theca when the sporules are ripe. If the calyptra be entire when it falls off, it is called *mitral;* but if it open first on one side, it is called *dimidiate*. The mouth of a theca is called its *stoma*, and is closed by a little lid, or *operculum*. The stoma is generally surrounded by a fringe of hair, called the *peristoma;* and when this is in two rows, the inner hairs are the *teeth*, and the outer ones the *cilia*. The cavity of the theca is called the *sporangium*, and in the centre is the *columella*, or axis. Sometimes the lower part of the theca is solid, when it is called the *apophysis;* and when this is

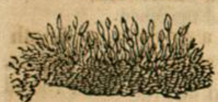

Fig. 83.—Moss.

196. Name the various mosses, and their peculiarities.
197. Define the technicals.

swollen on one side, it is said to be *strumose*. Besides their thecæ, mosses have other reproductive organs called *staminidea*, which partake of the nature of buds.

190. *The characeæ*, or *stoneworts*, have globules in the axils of their leaves, filled with a mucilaginous fluid, in which are numerous convoluted filaments, and minute spherical particles, or *nucules*, resembling buds, from which the young plants are raised. These plants grow under water, and their slender transparent stems are sometimes found incrusted with stony matter; hence the term *stoneworts*.

191. *The hepaticæ*, or *liverworts*, are small creeping plants, having their leaflets imbricated over each other, differing from the mosses in the form of the capsule. Their organs of reproduction are globular bodies, containing a minutely granular substance, escaping by an aperture; or they are capsules, containing sporules and spiral filaments, covered at first by a calyptra, at length rising on a peduncle, and opening by valves (see fig. 84).

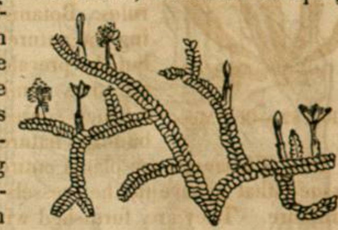

Fig. 84.—Liverworts.

Fig. 85.—Lichens showing their Reproductive Organs.

192. *The lichenes*, or *lichens*, vary exceedingly in form and texture, and comprise all those scaly ash-coloured substances

198. What of the stoneworts and liverworts?
199. Describe the lichens, and their organs.

which grow on rocks, old walls, trunks of trees, &c. They may be said to consist of lobed fronds, or *thalli*, of a leathery texture, on the surface of which the reproductive matter appears in powdery or gelatinous expansions. The reproductive organs assume two common forms; *soridia*, or heaps of pulverulent granules scattered over the upper surface of the thallus; or *apothecia*, which are small cup-like specks, surrounded by a rim, and containing *asci*, or tubes, filled with sporules (see fig. 85).

193. *The algæ* are all strictly aquatic plants, growing either in salt or fresh water. By far the greater number of algæ inhabit the ocean; hence the general term *sea-weed* has been applied to this class of vegetation. They are destitute of leaves, properly so called, and consist of fronds of various forms, being either globular, filamentary, capillary, tubular, or laminar; and these again being either branched, continuous, or articulated. They are reproduced by sporules, contained in *sporidia*, which are usually situated in the substance of the plant, (see fig. 86).

Fig. 86.—Bladder-Wrack (*Fucus vesiculosus*); *a*, Vesicles containing the Spores; *b*, Section of the same.

194. *The fungi*, or *mushroom tribe*, which constitute the lowest forms of vegetable development, are extremely diversified in their size, shape, colour, and consistence. They are entirely composed of cellular tissue, and some are even apparently animated; so that they are regarded as connecting links between the vegetable and animal kingdoms. The

200. Name the varieties of sea-weed.
201. What of mushrooms?

Agaricus campestris, or common field-mushroom, is one of the best known, and forms the type of the family; but the mould on cheese, stale bread, the mildew on trees, the rust on corn, and many other minute and yet unobserved appearances of a similar nature, are all fungi. They have no fronds or leaves; and are hence termed *aphyllous*. Their organs of reproduction consist of sporules, lying loose on the tissue of the plant, or collected in certain places, which are distended by their aggregation. Figure 87 exhibits some of the most familiar forms of the fungi.

Fig. 87.—Agaricus Volvaceus (1), and Campestris (2).

195. *The manner in which the reproductive organs of flowerless plants perform their functions* is as yet but little understood by botanists. "We are entirely ignorant," says Professor Lindley, "of the manner in which the stems of those that are arborescent are developed, and of the course taken by their ascending and descending sap—if, indeed, in them there really exist currents similar to those of flowering plants; which may be doubted. We know not in what way the fertilizing principle is communicated to the sporules or reproductive grains; the use of the different kinds of reproductive matter found in most tribes is entirely concealed from us. It is even suspected that some of the simplest forms (of algæ and fungi, at least) are the creatures

202. What link of the scale of being are these regarded?
203. What is known of the reproductive or vital organs of flowerless plants?

of spontaneous growth; and, in fine, we seem to have discovered little that is positive about the vital functions of those plants, except that they are reproduced by their sporules, which differ from seeds, in germinating from any part of their surface, instead of from two invariable points."

PHENOMENA OF VEGETATION.

196. *In addition to the ordinary functions of the organs,* which are the same in all plants of the same genus, there are certain anomalous functions which cannot be reduced to regular laws, and which differ in different species even of the same genus. The most remarkable of these are the occasional *irritability* of plants, their *colours, fragrance,* and *tastes.*

IRRITABILITY, AS DEPENDENT ON ATMOSPHERIC INFLUENCE, ON CONTACT, AND ON INTERNAL EXCITATION.

197. THE IRRITABILITY of animals depends entirely on their nervous system; but as plants have no nervous system, their irritability is more difficult to be accounted for. Dr. Darwin, indeed, asserts that plants are only an inferior kind of animal, and that they, or at least some of them, have a brain and a stomach, and are endowed with the lower senses. According to this fanciful doctrine, the medulla or pith was made the seat of sensation, and was considered analogous to the spinal marrow of animals. The doctor, however, had no followers, as his hypothesis presented too many difficulties to be even partially believed.

198. *The principal phenomena* of vegetable irritability may be divided into three kinds; namely, those caused by atmospheric influence, those depending upon the touch of other bodies, and those which appear to be perfectly spontaneous.

199. *Atmospheric influence occasions the closing of the leaves over the extreme point of the young shoot at night,* as

204. What phenomena of plants are named?
205. How is irritability accounted for?
206. Examples of atmospheric influence.

may be observed in the chickweed and several other common plants. The folding of some flowers in the absence of the sun, and the opening of others as soon as that luminary has withdrawn its beams, are ascribable to a similar cause. The white marigold closes its flowers on the approach of rain, and the dwarf calendrina folds up its bright crimson corolla about four o'clock every afternoon. The evening primrose, on the contrary, will not open its large yellow flowers till the sun has sunk below the horizon; and the night-blowing cereus only expands its magnificent blossoms about midnight. Some flowers are so regular in their hours of opening and shutting, that Linnæus formed what he called *Flora's Time-piece,* in which each hour was represented by the flower which opened or closed at that particular time. Thus—tragopogon pratense opens from three to five; papaver nudicaule at five; hypochæris maculata, six; nymphæa alba, seven; anagallis arvensis, eight; calendula arvensis, nine; arenaria, nine to ten; and mesembryanthemum at eleven.

200. *Solar light is the principal agent in producing these phenomena;* but, in some cases, flowers have been known to open by artificial light. De Candolle found blossoms expand beneath a lamp nearly as well as beneath the sun itself; and the crocus-flower, which closes at night, has been known to expand as wide as possible when gently exposed to the light and heat of a fire. Besides the cases in which flowers open and shut their corollas by the influence of light, instances are known in which merely the petals roll up by day, and resume their natural shape after sunset, as in some of the silenes.

201. *The sleep of plants,* a term first proposed by Linnæus, is a very remarkable phenomenon. In compound leaves, the leaflets fold together, and the common stalk droops; while in other cases—as, for example, in the chickweed—the leaflets fold over the bud of the young flower, as if to protect it from injury from either the cold of night

207. What of Flora's Time-piece?
208. The effect of solar light.
209. What is the sleep of plants?