the external layers, minute, chlorophyllose and duct-like. Capsules cylindrical, gymnostomate? and peristomate. Teeth eight or sixteen. Calyptra mitriform or dimidiate. Mosses remarkable for the pale colour, iridescence, and structure of the cells of their leaves: growing on the earth, on rocks, or on trees.

Genus 1. Octoblepharum, *Hedw.*
2. Arthrocormus, *Dzy. et Molk.*
3. Leucophanes, *Brid.*
4. Schistomitrium, *Dzy. et Molk.*
5. Leucobryum, *Hampe.*

Tribe XIII. Sphagnaceæ.

Cells of the leaves dimorphous, prosenchymatous, the larger colourless, perforate, often containing annular fibres; the smaller chlorophyllose, placed between the larger. Capsules gymnostomate. Calyptra covering the whole capsule. Large mosses, with erect stems, pale or rose-coloured leaves, and globose sessile capsules: growing in bogs.

Genus 1. Sphagnum, *Dill.*

PROCEEDINGS OF LEARNED SOCIETIES.

ROYAL INSTITUTION.

Friday, February 7, 1851.

On Metamorphosis and Metagenesis. By Professor Owen.

The Lecturer commenced by passing under review the Linnæan characters of Minerals, Vegetables, and Animals, and the subsequent distinctions which had been proposed for the discrimination of the two latter kingdoms of nature. After discussing those founded on motion, the stomach, the respiratory products, the composition of the tissues, and the sources of nourishment, it was shown that none of these singly define absolutely the boundaries between plants and animals; it requires that a certain proportion of the supposed characteristics should be combined for that purpose.

The individuals in which such characters are combined are specially defined members of one great family of organized beings, and the supposed peculiarly animal and vegetable characters taken singly, interdigitate, as it were, and cross that debatable ground and low department of the common organic world from which the specialized plants and animals rise; and there are numerous living beings with the common organic characters that have not the distinctive combined superadditions of either group.

Between the organic and inorganic worlds the line of demarcation may be more definitely drawn. The term 'growth' cannot be used in the same sense to signify the increase of a mineral and of an organism. The mode of increase is different: there is a definite limit to it in the organic kingdom, and something more than mere growth takes place in the progress of an organism from its commencement to maturity. This was exemplified by reference to the human subject, to the lion which acquires its mane, to the stag which gets its horns, and to the change of plumage in birds during the course of growth. The changes of form and character are still more remarkable in the kangaroo ; and in the frog they are such as to have received the name of '*metamorphosis.*'

The development of the frog was traced to its exclusion from the egg in the form of a fish, with external gills, a long caudal fin, and without legs.

The internal skeleton, like the external shape, is adapted for aquatic life.

Only those parts are ossified which are to be retained in the mature state. The vertebræ are at first biconcave, as in fishes, with invervening spherical elastic balls filled with fluid : they are converted into ball and socket joints by the ossification of the sphere, and its anchylosis to the back part of the vertebræ. The pelvis and hind legs are progressively developed; and, whilst this change is proceeding, the tail is undergoing proportional absorption. The chief change in the skull of the larva is operated in the lower or hæmal arches and their appendages. The maxillary arch is widened and provided with teeth, and the horny mandibles are shed. The mandibular arch retrogrades as well as expands. The hyoidean undergoes a remarkable change of size and shape, and the branchial arches are absorbed, excepting a small portion which is converted into the hinder 'horns' of the hyoid for supporting the larynx.

The scapular arch, which at first was connected with the occiput, whilst supporting the branchial heart—its primary function, begins, as soon as the fore legs bud out, to retrograde, and the sternum is developed to complete the 'point d'appui' for the fore limbs.

The food of the larva is chiefly the soft decaying parts of aquatic plants ; it has a horny beak, a long alimentary canal disposed in a series of double spiral coils : but, as its frame undergoes the changes adapting it for life on land, and a purely animal diet, the mandibles are converted into jaws and teeth, and the long spiral intestine into a short and slightly convoluted one.

Soon after the external gills have reached their full development they begin to shrink and finally disappear ; but the branchial circulation is maintained some time longer upon internal gills : by anastomoses between the principal branchial vessels these are converted into the aortic arches, carotids and subclavians ; the internal gills with the cartilaginous hoops supporting them are absorbed, and lungs and glottis for breathing the air directly are developed.

Thus an animal formed for moving in water is changed into one adapted for moving and leaping on land ; a water-breather is converted into an air-breather ; a vegetable feeder into a carnivorous animal : yet the series of transmutations are limited to the nature of the species and produce no other. The frogs that croak in our marshes are as strictly batrachian as those that leapt in Pharaoh's chamber ; their metamorphoses have led to nothing higher than their original condition, as far as history gives us any knowledge of it. With each successive generation the series of changes recommences from the old point, and ends in a condition of the animal adapted to set the same series again on foot.

Having traced the principal stages in the metamorphosis of an animal from a swimmer to a leaper, the Lecturer next took an instance where one begins life as a burrower or a crawler, and is converted into an animal of rapid and powerful flight.

Most insects quit the egg in the form of a worm, which masking, as it were, a different and higher form, is called the 'larva'; it is active and voracious—but usually falls into a kind of torpor, during which the changes take place which issue in the flying insect; during the passive stage of metamorphosis it is called a 'pupa'; the last volant stage is the 'imago.'

The chief steps in the metamorphosis were traced as they affect the outward form, the digestive organs, the circulatory, and respiratory, and nervous systems.

The main differences in the metamorphoses of insects relate to the place where, and the time during which they are undergone. The young cockroach and the little aphis, which were first acephalous and apodal, and then had thirteen equal segments, with soft unjointed legs, proceed to acquire a distinct head with antennæ, a thorax with three pairs of long jointed legs, and an abdomen, before they quit the egg; they thus enter upon active life under the guise of a crab, instead of a worm. With regard to the *Aphis*, that insect, instead of proceeding to perfect its individual development, may at once begin the great business of its existence by parthenogenetic procreation. Bonnet's experiments, which first brought to light this marvellous fact, have received uniform confirmation from all subsequent inquirers, and no natural phænomenon is now better determined.

From seven to eleven successive generations have been traced before the individual has finally metamorphosed itself into the winged male or winged oviparous female.

In autumn, when the nights grow chilly and long, the oviparous imago completes her duty by depositing the eggs in the axils of the leaves of the plant, where they are protected from the winter frost, and ready to be hatched at the return of spring. Then recommences the cycle of change, which being carried through a succession of individuals and not completed in a single life-time, is a 'metagenesis' rather than a 'metamorphosis.'

This phænomenon, which until very recently was deemed an exception, and a most marvellous one, in Nature, now proves to be an example of a condition of procreation to which the greater part of organized Nature is subject.

The Lecturer was inevitably limited in his choice of illustrations: and proceeded to an instance of metagenesis from the radiated subkingdom of animals.

The stages of this metagenesis have been best and most completely traced in the *Medusa aurita*, by Siebold, Dalyell, Sars, and others.

The first step was made by Siebold, who, in 1839, traced the development of the *Medusa aurita* from the egg to a stage resembling a ciliated monad, then to a lobed rotifer, and next to a long-armed polype.

This polype stage of the *Medusa* had been previously recognised in 1788, but without a suspicion of its true nature, by O. F. Müller, who called it *Hydra gelatinosa.*

It was next observed, and its habits more fully described, by Sir John Dalyell, in 1834, as *Hydra tuba*: and in 1836 he made known its singular metamorphoses into forms which Sars had previously described as *Scyphistoma* and *Strobila*; and Dalyell saw the spontaneous division of the latter into a pile or series of small Medusæ. All the stages of the metagenesis were independently noted by Sars, who described them in 1841.

The difficulty of accounting for the presence of Entozoa in the interior parts of animal bodies is rapidly disappearing as the knowledge of their course of development advances.

The principal stages of this development were described in a small worm (*Monostoma mutabile*), parasitic in the air-cells, intestines, and peritoneal cavity of many water-fowl.

The ovum is converted into a ciliated monadiform embryo, which escapes from the bird, and swims about freely in the water. A clear mass may be discerned in the interior which exhibits independent movements. This body is liberated, grows rapidly, and generates in its interior a number of independent organisms provided with a cephalic speculum and a caudal appendage, referable by their form to the genus *Cercaria.* They are very active and insinuating, could even bore through the skin by the sharp needle-like armature of the head, and somehow or other do, under the guise of the *Cercaria,* again get access to the interior of the water-fowl; fall into a state of torpor; become circular flattened pupæ; and are finally metamorphosed into Monostomes—a sluggish pendent parasite utterly deprived of the power of existing in water, or of gaining access, as a Monostome, to the interior of any animal.

Steenstrup, who has the merit of having first grouped together and pointed out the analogies of the different stages in the animals that undergo these successive changes, generalizes the facts under the phrase of 'Alternate Generation,' and he calls the procreant larvæ 'Amme,' or Nurses, and 'Gross-amme,' or Grand-nurses. There is no particular objection to these names; but we naturally desire to know on what power the metageneses depend.

Professor Owen thought the key to the power was afforded by the process which the germinal part of every egg undergoes before the embryo begins to be formed.

A principle, answering to the pollen, that fertilizes the seed of plants, is the efficient cause of these changes: its mode of operating is best seen in the transparent eggs of some minute worms; the principle manifests itself as a transparent, highly refractive globule in the centre of the egg; it then divides; and each division, attracting the vitelline matter of the egg about it, divides that matter into two parts. This division is repeated with the same result, until the principle has diffused itself by indefinite multiplication through the whole yelk which then constitutes the 'germ-mass.'

The next stage is the formation of the embryo: certain of the minute subdivisions called 'nuclei' or nucleated cells, combine and coalesce to constitute the tissues of the embryos: they are afterwards incapable of generating. If all be so metamorphosed, the organism cannot procreate of itself; but if a part only of the germ-mass be metamorphosed into tissues, the unchanged remnant may, if nutrition, heat, and other stimuli are present, repeat the same actions as those that formed the first germ-mass, and lay the foundation of future embryos.

In proportion to the amount of the substance of an organism which retains the primitive condition of cells, is the power of producing new individuals without receiving a fresh supply of the pollen-principle.

Thus in a plant, when the seed has received the matter of the pollen-filament, analogous changes take place to those that have been described in the animal egg, and the embryo plant appears in the form of the cotyledonal leaf with its radicle or rootlet. From this shoots forth another leaf with its stem: and the cellular substance of the pith with its share of the pollen-principle goes on developing fresh leaves and leaf-stalks; until a provision for developing fresh pollen is made by transforming certain individual leaves into a higher form of the 'phyton' or elemental plant. Thus a generation or 'whorl' of leaves assumes the character of sepals, another that of petals, a third that of stamens, a fourth that of pistils: and in the two latter forms we recognise the analogues of the perfect male and female of the animal.

The development of the compound polype follows very closely the stages of the compound plant, which we call shrub or tree: the ovum, like the seed, having received the pollen-principle, is converted into countless cells and nuclei of cells by the process for diffusing that principle through, or of assimilating it with, the matter of the egg. Then certain germ-cells are metamorphosed into a ciliated integument, and the larva starts forth in a state answering to the cotyledonal leaf of the plant: the ciliated larva settles, subsides, and shoots up a stem from which a digestive polype is developed, answering to the leaf: but the pollen-force not being exhausted, a second branch and polype are developed, and so on until a preparation is made for a fresh supply of pollen-force, by metamorphosing the polype into a higher form of individual; and this, in many compound polypes, is set free in the shape of a minute medusa.

The true nature and relation of the individual polype to the compound whole is well illustrated by the propagations of the Aphides.

By comparing with the diagrams of the metagenesis of the plant and polype, that of the Aphis, in which was represented the corresponding stages intervening between the ovum and the perfect male and female individuals of the *Aphis*, the analogy between these stages in the plant, the polype, and the insect, was shown to be both true and close. The microscopic fertilizing filament of the male *Aphis* answers to the microscopic pollen-filament of the male leaf or 'stamen;' the ovum of the female *Aphis* to the ovule of the female leaf or pistil: by their combination the fertile ovum results. The same processes of cell-formation ensue, and the embryo *Aphis* is formed by the combination and metamorphoses of certain of these secondary germ-cells; but it retains the rest unchanged in its interior, which may be compared with the cells of the pith of the plant, and with the cells in the corresponding more fluid part of the pith of the polype. Under favourable circumstances of nutriment and warmth, certain of these cells repeat the process of embryonic formation, and a larval individual like that from the ovum is thus reproduced; which is only not retained in connection with its parent, because the integument is not coextended with it.

The generation of a larval Aphis may be repeated from seven to eleven times without any more accession to the primary pollen-force of the retained cells than in the case of the zoophyte or plant; one might call the generation, one by 'internal gemmation'; but this phrase would not explain the conditions essential to the process, unless we previously knew those conditions in regard to ordinary or external gemmation.

At length, however, the last apterous or larval Aphis, so developed, proceeds to be 'metamorphosed' into a winged individual, in which either only the fertilizing filaments are formed, as in the case of the stamens of the plant, or only the ovules, as in the case of the pistil. We have, in fact, at length 'male and female individuals,' preceded by procreative individuals of a lower or arrested grade of organization,—analogues to the gemmiparous polypes of the zoophyte and to the leaves of the plant.

The process was described for its better intelligibility in the Aphides as one of a simple succession of single individuals, but it is much more marvellous in nature. The first-formed larva of early spring procreates not one but eight larvæ like itself in successive broods, and each of these larvæ repeats the process; and it may be again repeated in the same geometrical ratio until a number which figures only can indicate and language almost fails to express, is the result. The Aphides produced by this internal gemmation are as countless as the leaves of a tree, to which they are so closely analogous.

It generally happens that the metamorphosis which has been described as occurring after the seventh or eleventh generation takes place much earlier in the case of some of the thousands of individuals so propagated; just as a leaf-bud near the root may develope a leaf-stem and a flower with much fewer antecedent generations of leaves from buds than have preceded the formation of the flower at the summit of the plant; or just as one of the lower and earlier-formed digestive polypes may push out a bud to be transformed into a procreative and locomotive polype. The same analogy is closely maintained throughout.

The wingless larval Aphides are not very locomotive; they might have been attached to one another by continuity of integument, and each have been fixed to suck the juices from the part of the plant where it was brought forth. The stem of the rose might have been incrusted with a chain of such connected larvæ as we see the stem of a fucus incrusted with a chain of connected polypes, and only the last developed winged males and oviparous females might have been set free. The connecting medium might even have permitted a common current of nutriment contributed to by each individual to circulate through the whole compound body. But how little of anything essential to the animal would be affected by cutting through this hypothetical connecting and vascular integument, and setting each individual free! If we perform this operation on the compound zoophyte, the detached polype may live and continue its gemmiparous reproduction. This is more certainly and constantly the result in detaching one of the monadiform individuals which assists in composing the seeming individual whole called 'Volvox globator'; and so likewise with the leaf-bud. And this liberation Nature has actually performed for us in the case of the Aphis, and she thereby plainly teaches us the true value or signification in morphology of the connecting links that remain to attach together the different gemmiparous individuals of the volvox, the zoophyte, and the plant.

The analogy between the procreating larvæ of the *Aphis*, the *Medusa*, and the *Coralline* is so true and so close, that if the larval Aphis be a distinct individual and not a part, so must be the strobila, the planula, and the gemmiparous leaf: if the succession of larval Aphides be truly described, as a succession of generations, so must that succession of planula, polype, and strobila which leads to the oviparous Medusa; and that succession of planulæ and nutritive polypes which precede the detachment of the free procreative medusoid polypes in the Coryne; and the like with the plant-generations preceding the flower.

It would have been easy, if time permitted, to multiply the illustrations of the essential condition of these phænomena. That condition is, the retention of certain of the progeny of the primary fertilized germ-cell, or in other words, of the germ-mass, unchanged in the body of the first individual developed from that germ-mass, with so much of the pollen-force inherited by the retained germ-cells from the parent-cell or germ-vesicle as suffices to set on foot and maintain the same series of formative actions as those which constituted the individual containing them.

How the retained pollen-force operates in the formation of a new germ-mass from a secondary, tertiary, or quaternary derivative germ-cell, the Lecturer did not profess to explain; neither was it known how it operates in developing the primary germ-mass.

The botanist and physiologist congratulates himself with justice when he has been able to pass from cause to cause, until he arrives at the union of the pollen-filament with the ovule as the essential condition of development—a cause ready to operate when necessary circumstances concur, and without which those circumstances would have no effect.

The chief aim of the present discourse was to point out the circumstances which bring about the presence of the same essential cause in the cases of the development of the successive generations completing the metagenetic cycle of the Aphis, the Medusa, the Polype, and the Entozoon. The cause is the same in kind though not in degree, and every successive generation, or series of spontaneous fissions, of the primary germ-cell must weaken the pollen-force transmitted to such successive generations of cells.

The force is exhausted in proportion to the complexity and living powers of the organism developed from the primary germ-cell and germ-mass. It is consequently longest retained and furthest transmitted in the vegetable kingdom; the zoophytes manifest it in the next degree of force; and the power of retained germ-cells to develope a germ-mass and embryo by the remnant of the pollen-force which they inherited, is finally lost, according to present knowledge, in the class of Insecta and in the lower Mollusca.

ZOOLOGICAL SOCIETY.

June 11, 1850.—W. Spence, Esq., F.R.S., in the Chair.

A Monograph of Scarabus, a genus of air-breathing Gasteropodous Mollusca. By Arthur Adams, R.N., F.L.S. etc.

Scarabus, Montfort.

Testa ovata, spira subobtusa, anfractibus compressis, varice utrinque instructis; apertura ovali intus utrinque dentata; peristomate non continuo, labro simplici, subexpanso.

The *Scarabi* have the eyes sessile on the inner bases of the tentacles, which are short and annulated; they live like most of the other genera of *Auriculidæ*, in the damp woods and mangrove marshes. None have been found in the African or American regions, but all the species at present known are from the East Indies.

Scarabus imbrium, Montfort, Conch. Syst. vol. i.; Férussac, Prodrome, p. 101; Chemnitz, Conch. vol. ix. pl. 136. fig. 1249 & 1250.

Helix scarabæus, *Linn.*—Helix pythia, *Müller.*—Bulimus scarabæus, *Bruguière.*—Auricula scarabæus, *Lamarck.*

S. testâ ovato-pyramidali, rufo-fusco variegatâ, longitudinaliter valdè striatâ; spirâ acuminatâ; aperturâ subrotundatâ, spiram æquante; labro posticè inflexo.

Hab. Island of Bohol, Philippines; in dry woods, under stones, and in earth; *H. C.* (Mus. Cuming.)

The large size, pyramidal form and strongly striated epidermis are peculiar to this species: the upper tooth on the inner lip is more triangular, and the posterior part of the outer lip is more inflexed than in *S. Lessoni.*