from what I think that I have seen in *Oscillatoria princeps*, seems to take place in this family, not from the conjugation of its cells, but from the division of their contents into zoospores. Much therefore remains to complete the history of this little plant; and this, unfortunately, can only be obtained by watching it long and narrowly in its proper habitat.

XXI.—*On the Contractile Tissue of Plants.* By Prof. Ferdinand Cohn*.

Prof. Cohn commences his interesting essay by remarking that, though modern discovery has rendered the boundary-line obscure between the animal and the vegetable kingdoms, with respect to the lowest organisms in each, yet the differential characters between the higher forms of each subkingdom remain sufficiently well marked. Nevertheless the phenomena of irritability and of movement in parts of many higher plants bear a general resemblance to those presented by the tissues of the higher classes of animals, though their active cause has been attributed to mechanical forces in connexion with structural peculiarities. Cohn addresses himself to the question whether these mechanical hypotheses are sufficient and satisfactory, or whether the movements and irritability of plants are not referable to structures homologous with those concerned in their production and manifestation in animals.

To solve this interesting question, Cohn appeals to observations made by himself and by a talented pupil, M. Krabsch, who was induced by the Professor to repeat, in the first instance, the old experiments of Treviranus and Morren on the irritability of the filaments of *Centaurea*, as a prelude to new researches. Köhlreuter established the fact of the irritability of the stamens of *Scolymus hispanicus*, *Serratula arvensis*, *Cynara scolymus*, and *C. cardunculus*, *Onopordum arabicum*, *Centaurea moschata*, *C. nigra*, *C. spinosa*, and *C. ragusina*, *Cineraria*, *Scabiosa glastifolia*, *S. benedicta*, *S. eriophora*, and *S. salmantica*, *Buphthalmium maritimum*, *Cichorium intybus*, and *C. endivia*, and *Hieracium sabaudum*. Sowerby noticed the contractility of the anthers in *Centaurea Isnardi*, and L. C. Treviranus made a particular study of the movements of the filaments of *Centaurea pulchella*, whilst Morren did the same for those of the *Centaurea ruthenica*. Krabsch especially studied the movements of the anthers of *Centaurea macrocephala*.

* Translated, in abstract, from the 'Abhandlungen der Schlesischen Gesellschaft für vaterländische Cultur,' Heft i. 1861, by J. T. Arlidge, M.B. & A.B. (Lond.).

To witness the phenomena of motion and irritability in the stamens, it is only necessary to isolate a floret, as of *Centaurea*, and to cut away one-half of the corolla in such a manner as to expose the stamens, from their point of attachment, their whole length. After a period of rest of a few minutes, the filaments, which have hitherto been straight and in close apposition with the central style, are seen to curve themselves outwards, leaving, however, their terminal anthers still closely applied to the upper part of the style. This bending proceeds until it reaches its maximum, when each filament stands out in a half-circle from the style. On now touching a filament with a needle, they all, so to speak, collapse and resume their vertical direction and close apposition with the style. Bearing in mind the fact that the filaments are fixed at their two extremities (at the upper by the anthers, which are immoveable, and at the lower by their insertion into the receptacle of the floret), it becomes evident that, to produce the remarkable curvature they exhibit, they must undergo considerable elongation. Indeed, the degree of curvature does not represent the whole amount of elongation; for the filaments necessarily affect the length of the anthers by the tension exercised upon them. The extent to which they pull upon the anthers may be demonstrated by cutting across one or more of them, when the lower half becomes drawn apart from the upper, and thrust upwards above the line of section. The maximum of this movement of the cut filament is stated to be half a millimètre.

The movements of the filaments in two species of *Centaurea* (viz. *C. macrocephala* and *C. americana*) were carefully measured by means of the micrometer, due regard being given to the temperature, time of day, and other conditions likely to influence the phenomenon. These measurements are given in detail; but it is unnecessary to copy them here, and we shall content ourselves by stating the general results of Cohn's inquiries.

1. The touching of a filament of *Centaurea* is at once followed by shortening, which, in its extent, bears a direct relation to the intensity of the irritation produced.

2. The irritated filament undergoes shortening in its entire length. All other parts of the flower seem incapable of a similar process.

3. The shortening commences from the moment of contact, and proceeds rapidly (though not so much so as to appear instantaneous) until it attains its maximum. A sudden act of irritation, as with a needle, induces the most complete contraction.

4. Hence it also follows that the impulse to shortening is transmitted from the point irritated to both ends of the filament, or from one end to the other.

5. The degree of shortening varies according to the age of the stamens, the temperature, and other influences which exalt or reduce their irritability, as, for instance, the integrity of the flower, and the condition of the other filaments when irritation is applied to one of their number.

6. The medium degree of shortening, in thirty-one measurements, was rather above twelve-thousandths of a Viennese line, or about one-eighth of the length of the filaments. Thus, a filament which, when extended, is 12 millimètres in length, shortens, when touched, to 10·5 mill. This estimate is within the truth; for the whole amount of contraction cannot be measured.

7. Immediately after the shortening has attained its maximum, elongation commences, and proceeds much more rapidly at first than subsequently. The curve, consequently, is much more abrupt at first, and of a larger arc afterwards. The same law obtains in the case of muscle after irritation.

8. The interval between the maximum contraction and the maximum extension varies in length : the medium time is about ten minutes; but in some instances only six, and in others fifteen, minutes elapse. The irritability depends greatly on the age of the flower : it is greatest when the style has not yet fully extended itself beyond the yet closed anthers encircling it; and it is lost when the style has reached its maximum length and the anther-cells are divergent, although the corolla do not then show the least sign of withering. It therefore follows that the period at which the stigma can be impregnated is subsequent to the loss of irritability on the part of the stamens.

9. By repeated irritation, a maximum contraction may be obtained and kept up for some time. Whether the irritability of the organ undergoes diminution, and may be eventually destroyed by long repeated excitation, is not determined. The decision of this question is theoretically of much moment; for if such decrease and loss occur, then the phenomenon of fatigue, as witnessed in muscular fibre, ranks also as a property of the irritable substance of plants. To solve the question, an appeal may be made to other plants exhibiting irritability, such as the *Berberis, Mimosa, Drosera,* and *Dionæa*; and in the two last-named examples experiment has positively shown that too often repeated contact paralyzes the irritability of their leaves.

10. By prolonged irritation of the stamens, their subsequent extension is found to decrease progressively, both in degree and in the rapidity with which it occurs.

11. The capacity of shortening themselves, even irrespectively of the irritation of an external excitant, continues in the filaments for a considerable time, though it gradually declines.

12. At first sight it might be supposed that the shortening

of the filaments independently of the operation of external excitants is a consequence of the drying up of their tissue; but such is not the case.

13, 14. On the contrary, this shortening is a consequence of an active process of contraction. That it does not depend on desiccation of the organs, Cohn proved by contriving in some experiments to keep them moist, and in others to immerse the whole sexual apparatus in water. In the former series the power of contractility remained, whilst in the latter their capability of rapidly shortening themselves on the application of an excitant was almost instantaneously lost, though, after a time, it gradually revived.

15. From these experiments it was undeniably established that the filaments have their maximum length at the epoch of their highest irritability, and that subsequently they continuously and gradually contract, and also that this phenomenon is not dependent on the hygroscopic conditions of the parts. These facts necessarily imply that a direct relation subsists betwixt the contractility of the filaments, the loss of their irritability, and the gradual death of their tissue. To demonstrate this, Cohn subjected the prepared sexual apparatus of a floret to ether, with the view of destroying its vitality by the vapour, when he found that the filaments shortened themselves greatly, whilst the style remained unchanged. To obviate the desiccating effects of the ether-vapour on the tissue in this experiment, he introduced water so as to keep the parts moist.

16. Mechanical contact is not the only excitant to active contraction, but electricity is so likewise, and acts powerfully when the current is transmitted through the sexual apparatus. Moreover, when the current is strong, the shortening is not succeeded, as after ordinary stimulation of the filaments, by elongation; on the contrary, their irritability is destroyed, and they remain shortened. Parallel phenomena have been noted by Schlacht and Pfluger in the leaves of *Mimosa pudica* when an induction-current traverses them; and by Nasse in the stamens of *Berberis.* The effects of a continued constant current Cohn has not yet been able to determine.

17. From the observations made, it is presumable that the lasting and permanent shortening of the filaments, with loss of irritability, is a symptom of its extinction, whether produced rapidly by ether-vapour, by water, or by strong electrical action, or whether it happens spontaneously and gradually. The shortening also appears in all cases, under similar circumstances, to advance at a constant minimum rate, whatever may be the cause of the extinction of irritability.

The proximate active agent in the process of shortening is the elasticity of the cell-tissue, or the property to which a structure owes its permanence of form and its capability of renewing that form after disturbance from any cause. Moreover, the elastic powers of the stamens differ, as in muscle, under different circumstances. In the irritable stage the elasticity is great, but the extensibility small; and on the contrary, when the irritability is lost, the elasticity is decreased, and the filaments can then be readily extended. Still the elasticity remains so far as to assert its power by shortening the filaments when the extending force is removed; and this holds true even after their vitality has ceased.

18. We may probably arrive at a better apprehension of the phenomena detailed by endeavouring to discover in what tissues the contracting and the extending forces of the irritable stamens reside. The filaments of *Centaurea* are composed of very delicate cells, mostly somewhat longer than broad. Their softness or delicacy is so great that they are easily crushed by the glass cover in a microscopical examination. They are cellulose in chemical composition, and covered by an epidermis consisting of still larger though very delicate cells, three to four times as long as broad. Their outline is gently undulating, and their protoplasm is thick and coarsely granular; externally they give off conical-cylindrical hairs from over the septa between adjoining cells, so that these hairs are themselves divided by the longitudinal septa, being, as it were, prolonged into them. A cuticle encloses both the epidermic or epithelial cells and the hairs growing from them. In the interior of each filament is a bundle of spiral vessels with prosenchyma-cells and air-passages.

The question is, whether the cellular structure possesses, as a whole, the extending and contractile power, or whether the several tissues distinguishable have different and special functions. Microscopic examination can afford no positive answer to this question; but the following deductions may be made:—

a. The contraction proceeds in the cell-structure at large. If not, contraction would involve folds or wrinkles at parts; and such are not discoverable. *b.* On the other hand, the vascular bundle in the centre exhibits no activity in the process of contraction; for in a contracted filament the vessels are not in a state of tension, but wavy. *c.* The stretching of the different parts varies in degree greatly; for when a filament is slit longitudinally, it curves itself spirally, and so that the cut surface occupies the convex side. This shows that the tissues nearest the epidermis undergo greater shortening. Morren has made the remark that the centre of motile stamens possesses contractile power, and that the superficial epidermis and cuticle constitute the elastic portion; but Cohn inclines to the opinion that the entire parenchyma possesses the properties of extensibility and contractility, together with those of contractility and elasticity; but he would not deny that probably the different layers of cells partake of these properties in various degrees.

19. Another question is, supposing contractility to reside in the cells, whether the cell-membranes or their contents are the active agents in its manifestation. Dutrochet's hypothesis of endosmose as the cause of plant-movements has given place to the hypothesis of Hofmeister; and Cohn is disposed to believe that the primordial layer or the proteine contents are endowed with contractility, and that the enclosing cellulose membrane gives the required elasticity to cells.

20. It is, again, necessary to determine whether the changes in form of contractile cells are exclusively effected by the shortening of the long diameter which may be actually recognized. Cohn can give no decisive opinion on this matter, but presumes that the decrease in length must be followed by an increase in the width of the cells. But, even after the solution of these questions, the problem would remain unsolved, On what histological qualities and relations does the circumstance depend, that cells should by irritation undergo a change of form, and, whilst contracting in one dimension, expand in another? But the same difficulty prevails with regard to animal contractile tissue on these physiological points.

21. On comparing together the several observations adduced, two interpretations are possible. In the filament of *Centaurea* two properties exist in a state of antagonism—viz. elasticity, a physical property independent of vitality, and seated in the cell-wall, and an expansive power, associated with living action, and probably referable to the cell-contents (the primordial lamina). So long as the living filament retains its irritability, the property of expansion predominates, and the filaments are consequently extended and curved, and most so when they are exempt from irritation, though still in a considerable degree after having been temporarily shortened in consequence of irritation. Again, as the expansive energy declines with the vitality of the filaments, the elasticity comes more and more into play, and causes a progressive shortening of those organs. Irritation acts in a certain measure as a momentary and partial death, and paralyzes the expansive power; and when the vitality of the stamens actually vanishes, elasticity assumes the entire sway, and gives rise to a maximum degree of shortening. Thus, according to this interpretation, the shortening of the cells after an external irritation is peculiarly a passive phenomenon; and the active power is displayed in their extension during life in general, and particularly during the period of elongation.

22. Another interpretation offers itself when the above observations are viewed in comparison with those made respecting the contractile tissue in animals; and although, in the higher animals, contractility is found in association with highly organized muscular fibre and nerve-tissue, yet, in the lowest animal organisms, contractility and irritability exist even without the formation of distinct cells, as in the sarcode of *Hydra*, of *Amœbæ*, &c.; consequently these properties as exhibited in plants become more correctly comparable with such similar endowments in the animal kingdom. The comparison of vegetable contractile tissue with true muscular structure can, indeed, be only by way of analogy, and not of homology.

23. The greatest analogy obtains between the smooth organic muscles of animals and the contractile tissue of plants. The effect of contraction on muscle is to shorten and thicken it: this effect is speedy, but the subsequent elongation more gradual; this latter likewise proceeds in a curvilinear manner, similar to what may be seen in the contractile filament of the plants. However, the contraction of muscular tissue exceeds in extent that witnessed in the contractile substance of the plant.

Again, in muscle, contractility is opposed to elasticity; for, like the filament, muscular fibre is endowed with a small amount of elasticity. The degree of elasticity of muscle is smaller, and the extensibility greater, in the contracted than in the extended condition; and, though not demonstrated, it appears probable that the contracted filaments are more readily and largely extensible than the outstretched ones.

Further experiments are needed to decide whether the elastic property of the contractile filaments in all cases follows the same laws as Weber has clearly proved to exist in muscles.

The most powerful excitant of muscle is electricity, by the medium, however, of the nerves. Its operation is nevertheless similar in the case of the motile filaments. Mechanical contact operates alike in the two structures, and affects the entire length of the contractile organ. But, besides electricity, there are several other stimulants of muscular energy, such as warm and cold water, vegetable poisons, prussic acid, ether, and chloroform, not yet experimented upon in the case of the stamens of *Centaurea*, but which, judging from their action on *Mimosa pudica*, may be presumed to react on their irritability much as they do on that of muscles.

24. With the facts now advanced, the differences subsisting between the motory phenomena of contractile filaments and of muscular fibre may be examined and compared. Now, the extended condition is considered to represent the passive and normal state of muscle, and its contraction an active condition

opposed to the natural elasticity of its tissue. On the contrary, in the filaments of the plant, elasticity seems to act as the shortening agent, and to represent the passive condition, whilst extension or elongation appears to be a state of activity. A difference such as this implies in the active causes in operation in the contractile parts of plants and animals is, however, not probable. Indeed, presuming the physiology of muscular action, as generally taught, to be correct, we may still assume that the contraction of the filaments, like that in muscle, is a sequel to the operation of an active force—of contractility—which has been suspended in consequence of irritation, and also associated, as is true of muscle at the moment of its activity, with a change in the elasticity of the tissues.

25. We should be in a better position towards understanding the true relations between the contractility of plant- and of animal tissue did we rightly comprehend the remarkable contraction which the withered filaments undergo. So far as concerns the fact itself, it appears not to be without analogies in the animal kingdom, among the lowest classes endowed with contractile parenchyma. For instance, in Amœbeæ and Foraminifera, the contractile processes are retracted on the application of an excitant, and also on the approach of death, and the whole animal shrinks into a smaller compass. So it is in *Vorticella* and in *Stentor*, and also in *Hydra*. Such analogy is more obscure in the muscles of the higher animals; yet Cohn believes that the rigidity after death is a fact of the same class.

26. It is improbable that contractility as exhibited in the stamens of *Centaurea* should be an isolated phenomenon in the vegetable kingdom. On the contrary, a very large number of facts are on record respecting many plants, parallel in kind to those detailed. The peculiar phenomena attributed to vegetable "*irritability*" are of this order: such are the movements of the stamens of *Berberis, Cactus, Cistus,* &c., of the anthers of Gesneraceæ and of the Stylideæ, of the labella of some Orchideæ, of the leaves of many Leguminosæ, Oxalidaceæ, Droseraceæ, &c., of the climbing stems and tendrils of many climbing plants and creepers—all more or less affected by external excitants, electrical, chemical, and mechanical. To the same category belong also those phenomena described as the sleep of plants (regulated by and dependent upon the intensity of light), the movements of all younger parts of plants towards the light, and those changes in form, lately remarked by Hofmeister, in all young shoots and leaves, which become curved by mechanical shaking.

27. It has been generally assumed that these phenomena of irritability in plants have nothing in common with those witnessed in animals, but are to be explained by the action of some me-

chanical forces. Hofmeister's researches have set aside the hypothesis of Dutrochet, of endosmotic force called into play by excitants; but the theory advanced in its place, that the movements are not dependent on shortening, but on an augmented expansion or turgescence as the effect of excitation, cannot itself be maintained. In this hypothesis, the pith, as being very full of sap, is assumed to take the most important part in producing the movements—an assumption which Cohn shows, from *à priori* considerations, to be untenable. Moreover, the positive fact above advanced, of the occurrence of shortening when a part is irritated, stands in direct opposition to this general hypothesis of Hofmeister; for, without doubt, the movements of the young shoots are of a similar nature to those of the stamens exhibited in *Centaurea*.

28. Cohn has, from the researches entered into, arrived at the conviction that the accepted dogmas of physiology are erroneous in ascribing sensation and motion to animals as characteristics—a conviction further strengthened by all the newly observed facts relative to the lowest grades of animal life, and the distinctions existing between animals and plants. Sensation in the higher animals is linked with sensory perception or sensibility, and with a medium of connexion between the sensorium and surface in the system of nerves; but in the lowest animals this complex apparatus is absent, and the whole tissue responds to impressions from without, these latter operating by the existence of what is called "irritability," or of a degraded sort of sensation. This low form of sensation must be also attributed to plants; for these organisms exhibit it in a threefold manner: 1st, by the property of receiving impressions from without, *i. e.* by *irritability*; 2ndly, by the property of responding to such impressions by internal movements and by changes in form, *i. e.* by *contractility*; and 3rdly, by the power of propagating these impressions from their point of contact to the tissues and parts around, which are themselves, as a result, thrown into action, *i. e.* by *diffusibility* of impressions. The action of excitants in developing irritability and calling forth movements is not simply and directly dependent on their mechanical, physical, or chemical characters, but the organized tissue has an organic modifying power upon them, and the irritation gives rise to internal movements resulting in change of form, the suspension of elasticity, or the production of heat, &c. This organic power is the *vis nervosa* of Haller.

29. When an act of irritation is propagated within the tissue, this again is dependent on an internal motor power, called into activity by the external impression, without which the internal movements necessary to diffusion could not take place. Thus,

when a nerve is mechanically, chemically, or electrically injured, and the muscles in relation with it are thrown into activity, this happens not by transmission of the mechanical or other force, but by the calling forth of a motor nerve-force which propagates itself along the nerves.

On applying flame to a leaflet in the compound leaf of *Mimosa pudica,* it is not only that particular leaflet that is affected (for if so, it might be fairly attributable to the direct effect of the heat); but all the other leaflets, and the entire leaf, including its attachment to the stem, are similarly affected, and collapse; and what is more, the direction of the propagation of the impulse varies according to the point at which it impinges. Indeed, it is impossible to reduce these movements to the level of mechanical results; and the same holds true when electrical is substituted for mechanical force.

All such facts and considerations concur in proving that the propagation of external excitation in *Mimosa* proceeds in the same mode as in animals; and there is little doubt that the vascular bundles constitute the special tissue adapted for this object, and that the phenomena of contractility depend upon a muscular tissue.

Though not so perfectly, these properties are also displayed in *Dionæa, Drosera,* and the stamens of *Centaurea.* The filaments of the last named contract themselves in their entire length when only one point is touched; and the act of contraction manifests itself by undulatory movements, just as in organic muscle. This fact is best shown by preparing the flower of *Centaurea* so that the filaments are left by themselves, attached below, but set free above by having the anthers dissevered from them. This done, the filaments curve themselves gently outwards, and look like the arms of a *Hydra* extended. In this state any one of the filaments may be irritated (as by the point of a needle), with the effect of inducing a series of movements; these at first being a bending of the fibre towards the side on which it is touched, followed by curvature to the opposite side, and, lastly, by undulatory movements along its entire length. On irritating the five filaments on different aspects, they are bent about in various directions, curving over and crossing one another.

So far, however, as observation has extended, it would seem that in *Centaurea, Dionæa,* and *Drosera* the power of conduction of external impressions is not located in any one tissue, but equally partaken by all, as is seen in the instance of those lowest animals that are destitute of definite nervous and muscular tissue.

30. On now collecting the facts that energetic movements

as the result of irritation are seldom observed in the vegetable kingdom, but that the anatomical structure of irritable tissues presents no appreciable characteristic peculiarities not seen in other vegetable tissue, and that the suceptibility to the excitation of light, as well as to that of mechanical and probably of electrical impulse, is possessed by all young vigorous tissues; and further, on comparing these phenomena with those of animal irritability, the conclusion forces itself upon us, that the faculty of responding to external irritation by internal movements and changes of form belongs to cells as such, and holds good as well in the vegetable as in the animal kingdom. To be irritable, to change its normal form as a result of excitation, and to revert to it after a while by its inherent elasticity, are characteristics of the living cell. In plants, these properties are met with only when the vital processes are in full activity, and therefore are particularly noticed during the period of flowering, when those processes are at their maximum. And here it may be remarked that the stamens, in which irritability is more frequently noticed, are the only organs in which an elevation of temperature, measureable by the thermometer, occurs, although doubtless a certain degree of heat is generated in all plant-cells by the chemical processes going on within them. So soon as the processes of life in an organ begin to fail in power, so soon also does their irritability decline, so far, at least, as its external manifestations are concerned.

These circumstances suggest a reason for the rarity of the phenomena of irritability and contractility existing in any considerable degree in plant-cells; but they furnish no ground for concluding that irritable tissues possess properties not to be found in other vegetable tissues; on the contrary, it is to be supposed that similar properties belong to all, but exist in an intensified degree, and for a certain epoch, in those parts where their results arrest observation. There is a difficulty in believing that, in possessing the faculties of sensation and motion, the animal kingdom, including its lowest and most simple representatives, partakes of vital endowments entirely denied to plants for the sole reason of their being plants.

There is a physiological differentiation in the organs and cells of the higher animals, which progressively declines as we descend the scale of animal life; and we find in the lower grades of animals the same tissue, and this, too, in a less elaborated form, carrying on functions which, in the higher, are shared in by two or more highly organized special structures. The same holds good in a higher degree with respect to plants, in which, as a rule, one and the same cell performs all the functions necessary to life, though in some cases certain cells are constituted into a homogeneous tissue for the more special (but by no means the exclusive) performance of one or other of those functions. The hypothesis now contended for is, that plant-cells possess irritability and contractility as do animals, though in a much less complete manner, and without the mechanism of the specially devised tissues—muscle and nerve. And whoever will deny to plants the property of responding by movements to the act of irritation because they possess neither muscles nor nerves, by similar reasoning should deny their capability of taking up nourishment because they have neither mouth nor stomach, or their power to circulate the sap because they have no heart, or their faculty of respiration because they are destitute both of lungs and gills. In short, the plant has, by the medium of the simple cell alone, to accomplish all that is effected in the higher animals by different organs in a more complete and efficient manner.

31. In the foregoing discussion, Cohn has contented himself by assigning to vegetable tissue the property of irritability and the power of responding to irritation, or the function of contractility; and he would leave to a more imaginative dissertation the task of claiming for plants the possession of localized sensation, of consciousness, and of volition—properties which, in his apprehension, are absent also in the lowest forms of animal existence.

If sensation, as manifested in animals, could be predicated of tissues which respond by movements to external irritation and in consequence of it, no difficulty would be found in proving its existence in the vegetable kingdom, and particularly by reference to the influence of light upon the green parts of plants, the leaves and stems, in the production of correlative movements.

32. The movements of the contractile filaments of *Centaurea* must be acknowledged as having a special purpose when the process of fructification in this plant and its allies is studied. The anthers in Cynareæ reach maturity before the stigma. When the apex of the style has as yet not advanced in length beyond the surrounding ring of anthers, the pollen already distends, and exudes from, the cavities of the anthers. If at this period, when the irritability of the filaments is at its maximum, the floret be touched, the filaments are immediately shortened, and the anthers, as a consequence, are simultaneously retracted; a quantity of lumpy pollen is at the same time seen to be extruded from the apices of the anthers. However, this pollen is not in a condition to fructify the stigma, in consequence of the peculiar disposition of hairs upon the nodule supporting the fissured apex, which prevent the passage upwards of the pollen to the yet closed stigma-orifice; and it is not until after the

filaments have lost their irritability that the stigma and pollen are mutually fitted for the process of fructification. This extrusion of pollen on primary contact has, upon such grounds, been designated "pollution" by Meyer. From the above facts, it follows that the several florets in the flower of *Centaurea,* although they have their anthers and stigma in immediate contact, are nevertheless incapable of self-fructification, are only apparently hermaphrodite, and, in point of fact, dichogamic.

It is further remarkable that the pollen-grains remain united in lumps, and therefore less diffusible in the currents of air as dust; and consequently the fructification, in these as in many other plants, is effected by the agency of insects. When an insect alights on a flower of *Centaurea,* it produces by its contact a retraction of the irritable filament and anther, and at the same moment a discharge of pollen from the apex of the latter, which adheres to the legs of the insect, and serves to fructify, not the stigma of that particular floret, which as yet is, in fact, unfit for the process, but the female organ of some other floret, arrived at maturity, in the same or, it may be, in some other flower.

The researches of Köhlreuter and others prove that this process prevails throughout the entire family of Cynareæ, and affords an explanation of the frequency of bastard forms in this section of the Compositæ, and particularly in the genus *Cirsium.* Conrad Sprengel has pointed out that the sexual organs in *Carduus nutans* do not simultaneously reach maturity, and that therefore the florets are dichogamic. Köhlreuter also states that the filaments in *Cichorium intybus* and *Hieracium sabaudum* are equally irritable with those of *Centaurea;* and the frequency of bastard forms in the Hieraceæ renders it probable that their florets are also dichogamic. The same condition is moreover presumable in the case of other plants with syngenetic stamens, particularly in that of the Campanulaceæ, Lobeliaceæ, Violaceæ, &c.

Köhlreuter has likewise announced the fact of the irritability of the filaments in Cacteæ and Cistineæ; and those of the former tribe offer themselves as peculiarly adapted to further researches on this matter, and particularly with relation to the effects of electricity on the contractile tissue of plants. The physiology of contractile tissues is still in its infancy; but we anticipate that its more profound investigation will only supply additional evidence in favour of the proposition which we believe is the starting-point for general physiology and the science of development, viz., that the principle of life, both in the animal and vegetable kingdom, is one and the same, multifariously diversified by different gradations in organization, and that all vital phenomena of living organisms are referable to the life of the cell.

33. The following is a summary of the foregoing researches on the stamens of *Centaurea*:—

1. The stamens shorten themselves, on mechanical contact, instantaneously throughout their length. This holds true, also, when only one point is touched, and also of all parts of those organs. The contraction amounts to one-seventh of their length, and, in certain conditions, to one-fourth. Simultaneously with their contraction, the stamens also become thicker.

2. After the shortening has attained its maximum, the filaments begin to extend themselves, and to acquire a curved condition similar to what occurs in an irritated muscle. After the lapse of ten minutes, they regain their former length.

3. Other excitants, especially a current of electricity transmitted through the filaments, produce immediate contraction.

4. The irritability of the filaments vanishes spontaneously after a while—in the living flower, about the time when the segments of the style expand themselves and the stigma is in a condition for fertilization. But, coeval with these changes, the stamens become progressively shorter, and, when completely deprived of their irritability, are only one-half the length they were when in the full possession of that property.

5. This persistent shortening, which must not be confounded with contraction resulting transiently from previous irritation, is a symptom of death, not a hygroscopic phenomenon. At the same time it is induced much more rapidly when the irritability of the stamens is destroyed by the vapour of ether, by immersion in water, or by strong electric discharges.

6. The shortening in death is chiefly an effect of elasticity, which, in the irritable filaments, is subordinate to an expansive power; but, in the dead or withered state, the antagonism of this latter is withdrawn, and the filaments become shortened to one-half their length, and are highly elastic, like threads of india-rubber.

7. The property of shortening resides in the parenchyma of the stamens, which presents no especial difference from ordinary cell-structure; and the vascular bundle is at least passive during contraction.

8. The foregoing, along with other similar researches, go to demonstrate that the cell-tissue of the filaments of *Centaurea* possesses irritability (in the sense used by Haller) and likewise an innate motor power, both these properties resembling in all essential points their like as found in the contractile and irritable parts of animals. This analogy does not imply the existence of muscles and associated nerves, as found in the higher animals, where a physiological differentiation of tissues prevails in order to qualify for the performance of functions of the highest

order, but points much more precisely to the irritable and contractile tissue of the lowest animals, which possess neither muscles nor nerves.

9. As it is, on the one hand, most improbable that these conditions should obtain in the tissue of the filaments of *Centaurea* as a solitary instance, so, on the other, it is much more credible that similar properties (motory phenomena consequent on irritation) prevail throughout the vegetable kingdom. That this is so, is exemplified in all those movements which have a recognized object, as those of the young parts of all plants towards the light, and in the curved motions of such parts induced by mechanical and electrical contact; and the conclusion is inevitable, that irritability and contractility, or, in other words, the faculty of undergoing changes in form or outline in response to external excitation, are not restricted to the animal kingdom, but, like assimilation, respiration, the distribution of nutritive juices, development, &c., are the vital endowments of the cell simply as such, and are manifested in plant-tissue only exceptionally with less distinct energy by reason of a simpler organization and weaker vital power.

10. Teleologically considered, the irritability of filaments is subservient to the production of movements in the Cynareæ and the florets of probably all the other Compositæ, in connexion with dichogamic fertilization, as the frequency of bastard forms in *Cirsium* and *Hieracium* indicates. In this process insects constitute the principal agents, causing by their contact the contraction of the stamens and the consequent extrusion of pollen from the anthers, and then carrying the pollen so discharged to other florets, the stigmas of which are (unlike the organ of the floret, with its highly irritable stamens, which has furnished the fertilizing powder) in a condition to receive it.

XXII.—*On the Japanese Species of* Siphonalia, *a proposed new Genus of Gasteropodous Mollusca.* By Arthur Adams, F.L.S. &c.

Genus Siphonalia, A. Adams.

Testa ovato-fusiformis, plerumque variegata, non epidermide induta; anfractu ultimo ventricoso, plerumque nodoso-plicato. Apertura antice in canalem curtum recurvatum desinens.

Most of the typical species comprising this group have been described by Lovell Reeve in his Monograph of *Buccinum.* They are, *B. cassidariæforme,* Rve., *B. lineatum,* Kien., *B. signum,* Rve., *B. modificatum,* Rve., *B. spadiceum,* Rve., *B. fusoides,* Rve., *B. hinnulus,* Ad. & Rve. Their operculum, however, is fusoid,