largely taken up with the Cycadophytes, and the author is seemingly greatly impressed with the analogies between the bisporangiate fructifications of the latter and those of certain angiosperms. The treatment of the flowering plants is very brief and, although avowedly incomplete, does not indicate any great knowledge of, or even interest in, the literature of the subject.

As is eminently proper in a book designed for a general audience, the author very fairly states all controverted questions and rightly refrains from arriving at decisions, which are indeed impossible in the present state of our knowledge. Without prejudice to his position he may, I think, be fairly said to favor the following propositions: That land plants probably arose from various specialized algal ancestors somewhat after the manner set forth in Church's speculations; that the vascular plants were consequently polyphyletic in origin and that the Rhyniaceae may have been reduction products of some algal stock; that the true ferns and the seed ferns were of independent origin; that there was a community of origin between the seed ferns and the Cordiatales, and that the conifers and the ginkgos took their origin from some cordiatalean-like ancestors; that there was a community of origin between the flowering plants and the Mesozoic cycadeoids, finally that on the whole the evidence is favorable to the truly Darwinian conception of an orderly and gradual evolution of the various plant phylae.

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SPECIAL ARTICLES

A MECHANISM FOR THE COORDINATION AND REGULATION OF THE MOVEMENT OF CILIA OF EPITHELIA

THAT the movement of cilia in epithelia is coordinated is a fact of universal observation, but a structural mechanism in epithelia, by which this coordination of movement is conditioned and facilitated, has not hitherto been demonstrated.

Many biologists, especially physiologists, finding nothing in the structure of living epithelia suggestive of a coordinating mechanism and no reference in the literature of morphology concerning a durable, structural organization adequate to account for coordination of ciliary movement, have concluded that such a mechanism is not essential and does not exist. To account for the observed coordination of ciliary movement in epithelia, G. H. Parker,[1] in 1919, definitely formulated his theory of "neuroid transmission" according to which the coordinating impulses that pass from cilium to cilium are conducted, not by structurally differentiated paths, but by virtue of "that elemental property of protoplasmic transmission from which true nervous activity has been evolved." According to Parker ciliated epithelia present favorable conditions for the study of this elemental form of transmission.

The regulation and control of ciliary movement, such that it is correlated with the changing conditions of the environment and physiological states of the organism, is also a fact that is established by observation and experiment, although there are biologists who assert that such regulation does not exist; ciliated epithelia, according to their view, being purely automatic in their movements and not adjustable to the changing states of the organism as a whole. J. L. Kellogg[2] holds to such a view, at least so far as the ciliated tracts of the palps of lamellibranch mollusks are concerned.

During the past year we have made careful cytological studies of ciliated cells and epithelial of the gills of several species of fresh-water mussels of the genera, Lampsilis and Quadrula, and have been successful in finding well-differentiated systems of fibers which fully satisfy all the requirements of coordinating and regulating mechanisms.

The differentiated mechanism we have been able to demonstrate in the latero-frontal ciliated epithelium of the gill of a species of Lampsilis is shown in Fig. 1, and is schematically represented in Fig. 2.

The cilia (C), in this type of epithelium, are paired, and members of pairs are fused at their tips (X). The number of pairs of cilia is approximately the same as the number of nuclei in the syncytial epithelium. A specialized cuticle is present at the external surface of the epithelium in which the cilia and their basal corpuscles (b) are implanted. In the proximal zone of cytoplasm, between the cuticle and the row of nuclei, a system of intra-cellular fibers or ciliary rootlets is chiefly distributed, although fibers belonging to the system may penetrate the cytoplasm between nuclei, and perhaps even to the basement membrane and the sub-epithelial layer of bipolar cells. This system of intra-cellular fibers may be analyzed as follows: each cilium splits, just below its basal corpuscle, into two fibers (m and n) which diverge at angles varying from 20 to 30 degrees, one to the right and one to the left in the plane of the row of cilia. The right hand branches (m and m′), originating from the members of a pair of cilia,

[1] G. H. Parker, "The elementary nervous system," Lippincott Company, 1919.

[2] J. L. Kellogg, "Ciliary mechanisms of lamellibranchs, with descriptions of anatomy," *Journ. Morph.*, Vol. 26, 1915.

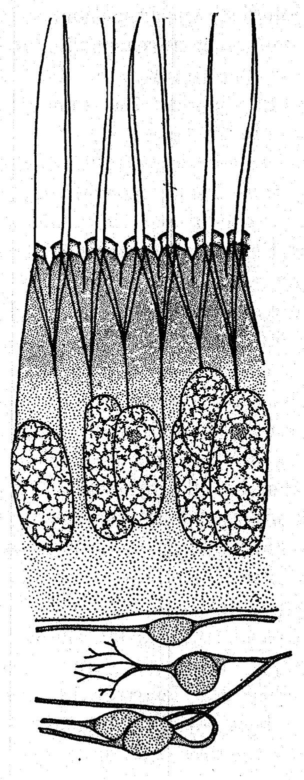

Fig. 1

gradually converge and join to form a single fiber (o), while the left hand branches (n and n′), join to form the fiber (o′). The fibers (o and o′) join with corresponding fibers derived from adjacent pairs of cilia, to form the fibers (p and p′) which may end on the nuclear membrane or penetrate the cytoplasm between nuclei. The part of this system, consisting of the fibers m, m′, n, n′, o and o′, forms a mechanism which is continuous throughout the extent of the epithelium and is postulated as that which provides a basis for the coordination of ciliary movement. The continuations of this system, through the fibers (p, p′, etc.) into the deeper parts of the epithelium, provide for the entry, into the system, of impulses, originating either in nuclei, the cytoplasm or bipolar cells of the subepithelium, by which movements of the cilia may be adaptively regulated in conformity with the state or needs of the organism as a whole.

In addition to the mechanism for the coordination of ciliary movement, just considered, another series of structures is present in each of the segments of the cuticle bounded by pairs of cilia, which apparently serves another purpose. One of these systems may be described as follows: a minute space (0) interrupts the continuity of the cuticle midway between pairs of cilia in the plane of the series of cilia. This space opens on the surface of the epithelium and, in section, appears to be formed between two fiber-like structures (r and l) which join the cuticular border above, in two-minute granules, and meet at the lower border of the cuticle, midway between the bases of the cilia of two pairs, in a similar granule. This latter granule is the meeting place also for two comparatively short, robust fibers (R and L) which originate, one from the nearest basal corpuscle of the pair of cilia on the right of the space, the other from the nearest basal corpuscle of the pair on the left, and it is the point of origin for a longer, unpaired, vertical fiber (S), which penetrates the cytoplasm to a depth below the cuticle about twice the thickness of the cuticle. This series of cuticular structures requires further study. The fibers (R and L) may be interpreted to be a part of the mechanism for the coordination of ciliary movement. The spaces in the cuticle and their attendant fiber-like differentiations possibly represent a structural adaptation for taking up stresses and strains in the highly gelled cuticle incident to ciliary movement.

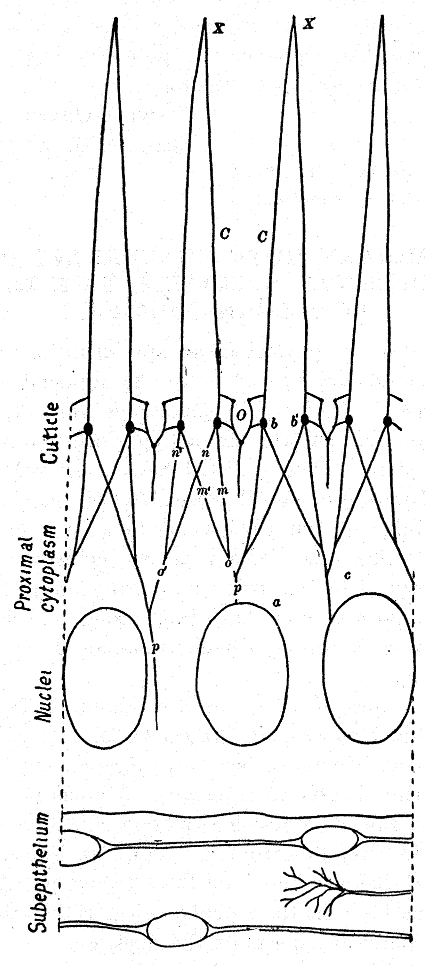

Fig. 2

It may be too early to indulge in sweeping generalizations, but we venture to predict that similar structural differentiations will be found in all ciliated epithelia. The facts of comparative morphology justify such a prediction. Function is so universally found to be associated with, and to depend upon, definite structural organization of living substance that in a tissue so specialized in function as that of a ciliated epithelium we may expect *a priori* to find in it a corresponding structural differentiation that is neither indefinite in form nor of temporary duration.

The results of our investigation of various types of ciliated cells, which rest upon experimental as well as morphological evidence, will be fully reported and discussed in a paper to be published in the *Journal of Morphology and Physiology.*

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PRELIMINARY NOTE CONCERNING PHYSIOLOGICAL SPECIALIZATION IN FOMES PINICOLA FR.

THE idea of physiological specialization in the fungi has undergone extensive development during recent years. In fact, a considerable amount of literature on this subject has arisen since about 1890, and it has been demonstrated beyond all reasonable doubt that physiological specialization exists in a great number of fungi belonging to widely separated families. The rusts have received particular attention in regard to this point and many interesting as well as important facts have been brought to light by the work of Eriksson, Dietel, Stakman, Hungerford and others.

Other genera of fungi, as, for example, *Erysiphe, Glomerella, Sphaeropsis, Rhyzoctonia, Septoria* and many others, have also been investigated, but, as far as the writer is able to ascertain, little has been done along the line of physiological specialization in the case of the wood-destroying fungi. It is true that some work has been done on these forms, but the emphasis has been on the morphological rather than on the physiological aspects of the question.

In regard to their general life history, many of the wood-destroying fungi differ from most other fungi in that they may, as a result of a single infection, inhabit a single host plant for a great number of years. For example, it is not impossible, nor even improbable, that *Echinodontium tinctorium, Fomes pinicola, Trametes pini,* etc., may grow in a tree as a result of a single infection for twenty-five, fifty or even a greater number of years. If, then, the character and general properties of the host plant exert any influence on the fungi infecting it, tending to produce physiological specialization, strains or varieties, it would not seem unreasonable to suppose that the chances for the production of such specialized forms or varieties among the wood-destroying Basidiomycetes would be very good.

There is also a very important practical aspect to this question. It is usually considered, in addition to other reasons, very poor practice from the standpoint of forest sanitation to allow infected trees to remain standing on an area upon which it is expected to raise future forest crops, even though these infected trees are of a different genus than those to be grown eventually. A concrete case will serve to elucidate this point. The white pine stands of the Inland Empire contain a considerable number of inferior species, such as white fir and hemlock. These latter species are often heavily infected with heartrot and many of such infected trees remain standing on the area after logging operations are completed. This is particularly true if broadcast burning does not follow the logging operations. These infected trees remain on the area at least during the early growth of the second crop. Very often the same species of fungi which cause the heartrot in these remaining trees also cause heartrots in the trees with which it is hoped to restock the area, as, for example, white pine. Thus *Trametes pini* causes more or less similar heartrots in fir, spruce, larch and pine. *Fomes pinicola* causes a red brown sapwood rot in spruce, larch, fir, pine and hemlock. *Echinodontium tinctorium* causes a heartrot in practically all the western true firs, Engelmann spruce, Douglas fir and western hemlock. Many other examples might be given, but the above are sufficient to illustrate the point. It is generally assumed, therefore, that these infected trees remaining on the area after logging constitute a menace to the future forest crop, even though it may be of a different genus. If, on the other hand, physiological specialization has developed to the extent that the strain common to white fir is limited to white fir, the Douglas fir strain to Douglas fir, etc., it is evident that the expense of falling and destroying these infected remaining trees might be eliminated when the forest sanitation is the only factor necessary to consider. The writer volunteers no expression of opinion on this point at this time, but merely calls attention to the situation.

It must be obvious that artificial infection experiments with the heartrot fungi are especially difficult and that it would take many years before any reliable data could be obtained. However, studies can be made on the physiological characteristics of these forms which may at least indicate the desirability of undertaking such artificial infection experiments, no matter how difficult or time-consuming the work may be.