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THE ADDRESS OF THE PRESIDENT
FOR 1912

THE DISSEMINATION OF FUNGI CAUSING DISEASE

By F. D. Heald

INTRODUCTION

A great deal has been written concerning the dissemination of seeds and this topic constitutes one of the regular subjects for treatment in every text book of elementary botany, but the dissemination of fungi is rarely mentioned. Even the text-books on fungi or plant diseases give but an inadequate account of this phase of mycology. Observations and experiments show that fungi provide for the dissemination of their offspring and the perpetuation of the species in many and varied ways and in many cases with great effectiveness. It is undoubtedly true that the agricultural and commercial practices of our present civilization have very materially assisted nature in spreading broadcast numerous parasitic forms as well as countless numbers of harmless saprophytes. That fungus pests are more numerous now in this country than in former years is not imaginary, but a stern reality. It is true that with the rapid development of plant pathology during the last decade we have had diseases of plants brought to our attention more than ever before. The history of our agriculture shows that with the intercourse between nations, fungus pests have been fre-

quently transported from one country to another. It is my purpose to consider briefly some of the ways by which fungi, and especially those causing disease, have been and are being disseminated.

HOW FUNGI ARE CARRIED

In the first place brief reference may be made to the state in which fungi exist during their transport. They may be carried as spores, as sclerotia, or as mycelium. Most fungi produce from one to several different kinds of *spores,* or specialized reproductive bodies, which provide for the perpetuation of the species, just as seeds of our Spermatophytes provide for the production of more seed plants. Spores may be active, that is, motile or capable of locomotion, but in most cases they are not endowed with the power of movement; in the former case their own activity may carry them in an aqueous medium to points far away from the parent plant that produced them, but in the latter they must be transported by some outside agency.

Spores are produced by fungi in enormous numbers. It is undoubtedly true that vast numbers of spores perish without ever finding suitable conditions for the production of new plants. It has been estimated for some species of mushrooms that only one spore out of twenty billion ever produce a new plant capable of spore production.[1] Many contain a minimum of reserve food and become exhausted in their first attempt to establish themselves; some are not able to withstand adverse conditions, such as desiccation, low temperatures, etc.; certain types germinate at once without a resting period and thus frequently fail to reach a suitable substratum upon which to develop. Conidiospores may germinate at once and they are generally produced in much greater numbers than the more resistant ascospores which frequently require a resting period. Figures give but a slight conception of the enormous numbers of spores produced by fungi but they serve to emphasize their prodigality in spore production. It has been determined by careful analytic methods that a *small* "spore horn" or "tendril" of the chestnut blight fungus may contain as many as 115,000,000 pycnospores. Cobb states that a single head of smuted oats may contain as many as 500,000,000 spores, or a sufficient number to give 1000 per square

foot if they were scattered evenly over an acre of ground. The marvel is that chestnut blight has not become more widely disseminated or oat smut a greater pest. Buller[1] estimates that a single wheat "berry" affected with bunt or stinking smut may contain over 12,000,000 spores; also that a single fruit body of *Polyporous squamosus* produced 11,000,000,000 spores, while the giant puff ball, *Lycoperdon boöista* L. produced the enormous number of 7,000,000,000,000 spores.

The production of *sclerotia,* or dense aggregates of fungus tissue by fungi is not uncommon, and these structures vary from minute masses to organs of appreciable size. Some fungi which produce spores but rarely, rely upon *sclerotia* for carrying the species over unfavorable conditions or for dissemination, while in other cases as in ergot, the sclerotium is only one stage in a rather complex life cycle. The origin of sclerotia is perhaps not uniform; they are probably due, in some cases, to the sterilization of a spore fruit, a pycnidium or perithecium, and certain fungi with scleropycnidia suggest this origin. Sclerotia appear to be very effective structures in perpetuating the species, if we may judge from the wide dissemination of certain fungi which are propagated almost entirely by this method. Why more fungi have not discarded the wasteful and uncertain process of spore propagation for the more certain method of sclerotia production can only be conjectured.

Fungi may be transported small or even great distances in the vegetative or *mycelial* stage. This mycelium may be included with some dead organic material which furnishes the substratum for its development or it may be included within the tissue of a plant or a plant structure upon which it is parasitic.

The following brief outline will give some of the principal ways in which the dissemination of fungi is effected:

I. Seed-borne fungi—Seed dissemination.
   1. By true seeds or fruits.
   2. By vegetative reproductive structures.

II. Air or wind-borne fungi—Wind dissemination.
   1. No explosive apparatus.
   2. Provided for by an explosive apparatus.
      (a) Forcible ejection of the fungus spores from the fungus fruit.

III. Water-borne spores—Water dissemination.
  1. Active or motile spores.
  2. Passive or non-motile spores.
IV. Insect-borne fungi—Insect dissemination.
  1. Insects as carriers.
  2. Insects as hosts.
V. Dissemination by other animals.
VI. Dissemination by agricultural and commercial practices.
  1. Transport of soil or manure.
  2. Transport of infected seed, nursery stock, or host: cultural stock.
  3. Transport of various commodities.

SEED-BORNE PLANT DISEASES

Many fungi have certainly solved the problem of dissemination in a most effective way by a relation to the seed of the host plant at some point in their life history. The fungus may be carried in either the spore, sclerotium or mycelial stage, upon or within true seeds, fruits or vegetative reproductive structures such as tubers, roots, bulbs, etc. Many of these seed-borne fungi are pernicious pests and have attained as wide distribution as the hosts themselves. Since plant diseases have been more intensively studied, more and more illustrations of seed-borne fungi have been brought to our notice. Some seed-borne fungi appear so constantly and generally upon some of our common crop plants that the attendant symptoms are not unfrequently interpreted by the untrained, as a normal accompaniment.

Anthracnose of the bean was one of the first diseases that was demonstrated to be disseminated by true seeds. This was first proved by Frank[2] in 1883, although later investigations have repeatedly claimed the honor. The mycelium of the fungus grows through the pod and into the seed during the period of maturing, and is there ready to resume its growth when the seed germinates. Experiments tend to show that this disease is introduced into a field very largely if not entirely by the ruse of infected seed, and that the spores are not generally spread from one field to another by the wind.[3] The Ascochyta blight of peas is another disease that behaves in a similar way[4] and Barre has recently shown that the widely disseminated anthracnose of cotton bolls is of a like nature.[5]

Since infected seeds, in so many cases, show no external evidence of the disease, the fungus is insured a wide dissemination, even with the most careful practice in the selection of apparently clean seed. Seed-borne fungi do not appear to be confined to any definite groups but this method of dissemination may prevail whenever the ripening ovary is infected. The downy mildew of the Lima bean and the white rust of the oyster plant constitute two excellent illustrations from the Peronosporales. The seed of the oyster plant may be so badly infested with the white rust as to entirely destroy the crop. The black-leg or Phoma wilt of cabbage,[6] a disease known in this country only during the past few years, was undoubtedly introduced from Europe with imported seed. Chapman[7] has recently called attention to the seed dissemination of three different onion diseases: smut due to *Urocystis cepulae;* brown mold, caused by *Macrosporium porri;* and downy mildew, referred to *Peronospora schleideniana.*

Fruits which function as seeds may also act as carriers of the parasite. Perhaps the best known and most familiar illustrations of this class are the seed-borne smuts of cereals, in which case the fungus is either on the surface of the caryopsis in the spore stage or has penetrated the pericarp and persists as a dormant mycelium. The loose smut of oats and the stinking smuts or bunt of wheat are good illustrations of the former, while the loose smut of wheat is one of the most notable illustrations of the latter condition. The bunt or stinking smut of wheat is undoubtedly more prevalent in our cultivated wheat fields than any similar species upon a wild host, or at least it was until the introduction of fungus "steeps" for its prevention. The ordinary process of harvesting is one that has very materially assisted in the dissemination of the fungus. When a wheat plant becomes infected with bunt every head produced by a single stool is smutted and all the "berries" are destroyed or transformed into "smut berries." Smutted plants may be scattered here and there through the field, and during the threshing process smutted berries are mixed with the normal sound grain; but many of the smut grains have the thin outer membrane ruptured, thus setting free the spore mass and the individual spores become scattered over the normal grains, lodging particularly in the "brush" and in the

suture.[8] Wheat may be so badly smutted that the normal grains are discolored by the large numbers of smut spores adhering to the berries. Of course nobody would think of using such grain for seed, but unfortunately smut spores may be present in minute quantity without giving any indication of their presence. It is possible, however, for the scientist to determine whether seed wheat is infected with bunt to even a slight extent. If the seed is washed or scrubbed in sterile water, the washings centrifuged, and the sediment examined with the microscope, the presence or absence of smut spores can be determined. This method was first used in this country by Bolley.[9]

In the loose smut of wheat wind dissemination of spores is combined with seed transport of the dormant mycelium. The inflorescence of wheat is completely destroyed and the dry, powdery mass of spores scattered by the wind. This maturity of the smut coincides nearly with the blossoming time of the normal head and the scattered spores may be responsible for a blossom infection. The fungus penetrates the developing ovaries and remains as a dormant mycelium hidden within the seed and exhibiting no warning of its presence. It is there, however, ready to resume activity with the awakening of the seed. Two diseases of beets are known to be carried by the seed (fruits): the Phoma rot of beets which has been so prevalent in Europe, and our well-known Cercospora leaf spot. The fungus (*Phoma betae*) which causes a rotting of the maturing beets also causes a serious damping-off of young seedlings.[10] A recent illustration has come to the writer's attention of chestnuts bearing the sclerotia of a fungus upon the surface.

Fungi which cause disease may be disseminated by the use of infected vegetative reproductive structures such as tubers, roots, rhizomes, bulbs or corms, for the production of a new crop. All such structures are gorged with reserve food and their tissues in a semi-dormant condition, easily invaded by certain types of fungi. In the majority of these structures the presence of an internal infection is revealed by some discoloration or disorganization of the storage tissue, or the fungus may be more superficial and exist in either the mycelial or the sclerotium stage. The Irish potato stands preeminent among the cultivated plants, for its numerous tuber-

borne diseases. In recent years many of these tuber-borne diseases have made such headway as to seriously threaten the potato growing industry in many parts of the country. Mention may be made of the late blight of the potato with its internal mycelium, the dry rots which also produce internal discolored areas pervaded by mycelium, scab with the more superficial corroded areas, potato wart with its external warty excrescences, and Rhizoctonia or potato rosette with superficial sclerotia. It has been shown by Massee that wart may also be transported by the use of tubers which show no external evidence of the disease, the spores being lodged in the "eyes." Some of these tuber-borne fungi may so exist in the soil as to infect perfectly healthy seed, but their original introduction can be traced in numerous instances to the use of infected seed.

The sweet potato affords several illustrations of diseases which are frequently introduced by the use of infected seed roots. Among these may be mentioned the black rot, due to *Sphaeronema fimbriatum*.[11] Several onion diseases may be introduced into new fields, by the use of infected sets or the use of imported bulbs for growing seed. Disease of the gladiolus are spread by the planting of corms already infected, and the same may be said concerning the bulbs of various greenhouse plants. As specific examples of bulb-borne diseases mention may be made of the Japanese lily disease, due to *Rhizopus necans*, and the anther smut of *Scilla latifolia* which develops from mycelium present in the bulb.

AIR OR WIND DISSEMINATION

The spores of many fungi are carried away from the parent plant by means of air currents. In general it may be stated that spores which are adapted to wind dissemination are liberated from the fungous fruit as a dry, powdery mass or are born singly or in loosely connected chains upon the ends of aerial sporophores, from which they are easily detached. The minute size of fungous spores makes unnecessary special devices for rendering them buoyant, and it is always possible to obtain various forms from the dust that settles to the surface of objects in closed rooms or in the garden or fields. The majority of the air-borne spores appear to be those of harmless saprophytic forms, and many of the statements made

concerning the part which wind plays in the dissemination of parasitic species are based largely on analogy rather than supported by direct experimental evidence.

Observational evidence is of little value in determining the part of air transport of fungus pests which are confined to a single host, but some heteroecious rusts give us *undoubted* examples of wind dissemination which so far as I know have never been definitely proved experimentally. The cedar rust which alternates between the cedar tree and the apple tree, and must pass from one to the other, is an excellent example. Susceptible varieties of apples standing adjacent to infected cedars will show a high percentage of infection, sometimes as many as 200-300 distinct spots to each leaf and the number of infections per leaf will decrease with the distance until the average is either one or less to each leaf. In addition, the rapidity and universality of the infection following the gelatinous stage of the cedar apple can be explained in no other way than by the wind dissemination of the sporidia, which Coons[12] has shown are forcibly discharged from the promycelia. The part which wind plays in the spread of our cereal rusts has probably been greatly overestimated. The old idea that rusts are spread gradually by the wind from the southern plains country to the north as the season progresses, has been largely abandoned as our ideas of their life habits have been modified. The theory of the wind dissemination of the cereal rusts gives a beautiful example of the inefficiency of reasoning alone as applied to the processes of nature.

It is undoubtedly true that many of our present day statements in regard to wind dissemination of spores would need revision if the rigid test of experimental evidence were applied to them. The application of scientific methods to the determination of the part which wind plays in the dissemination of parasitic fungi opens up an interesting field for investigation. It may not be amiss to mention briefly some of the methods which may be utilized, and it may be stated at the beginning that these have already yielded valuable results in the few cases where tried.

In the employment of the *exposure plate* in the field under natural conditions the pathologist is but imitating the bacteriologist.

As far as I have been able to determine this method was first employed in this country in the field for determining the prevalence of parasitic fungi by Wolf[13] at the writer's laboratory in 1907. It had, however, previously been used by Saito in Japan. It should be emphasized in this connection that the exposure plates should be made under natural conditions if we are to obtain reliable results. Erroneous conclusions may be drawn from results obtained under artificial conditions even if they are obtained from field experiments. It is evident that this method is of value only when the spores of the pathogens under investigation will germinate upon the medium that is available. There are many parasitic forms the spores of which will not germinate upon the ordinary culture media, and in investigating the prevalence of these spores this method is clearly at fault. Exposure plates may be made in the field or in the laboratory with the substitution of an artificial air current. As an illustration of this type, the experiments of Fulton[14] with the spore horns of the chestnut blight fungus may be mentioned, although his negative conclusions would have been obtained by *a priori* reasoning.

It is at once evident that the exposure plate can give no exact quantitative results, but only the relative abundance of the forms obtained. The aspiration of the air through a "spore trap" and the determination of the number of spores per unit quantity of air can be readily performed by the employment of the ordinary bacteriological method. This method was used by Wolf in 1907 and has recently been employed by Anderson.[15] The poured plates in this method do not reveal the possible presence of spores which will not germinate upon our culture media. In order to determine the presence of these, other methods must be employed. There are two methods suggested which are somewhat comparable to the two just outlined. First, if quantitative results are not desired a glass funnel, the inner surface of which is coated with glycerine, may be exposed for a certain length of time in the open and the spores which fall into it washed down with sterile water and the washings centrifuged, after which the sediment thrown down may be examined with the microscope. If quantitative results are desired the aspirator should be used, the contents of the sugar tube dis-

solved in a known volume of sterile water, all or a unit quantity centrifuged and the sediment examined microscopically by the use of the Leitz-Wetzlar counting apparatus. The results of the microscopic tests may be substantiated by inoculations made by using a suspension of the spores obtained from the air analyses, and in certain cases this method can be used to good advantage.

Inoculations by wind-borne spores under controlled conditions has been used in some cases for determining the part which this method of transport of spores plays in the life history of the fungus. As an illustration, the inoculations with chestnut blight fungus made by Anderson may be cited. The wounds were protected so as to exclude insects and spores washed down the tree by rains.

A large number of fungi, the spores of which are disseminated by air currents, produce the spores in such a manner that they are easily detached and carried away by the wind or in a dry powdery mass. In such cases there is no explosive apparatus that ejects the spores into the air and it is entirely the force of air currents that sweep them away from some exposed position, or they are borne in such a manner that they rattle out of the fungous fruit, frequently as a result of agitation of the host plant by the wind.

In many fungi, particularly the ascomycetes and basidiomycetes, the spores are forcibly ejected into the air[1] and can then be swept away from the fruit by the wind. It should not, however, be concluded that all fungous spores that are forcibly ejected, are adapted for wind dissemination. There are numerous cases in which the forcibly ejected spores are not adapted for wind dissemination but after they have come to rest are removed to more distant locations by other agencies.

The loose smuts of cereals and other grasses which produce myriads of spores in the deformed or destroyed inflorescences of their hosts are supposed to be disseminated largely by wind-borne spores. The powdery condition of the spores, and their elevated position upon the host certainly suggests this method of transport. The uredospores and aecidiospores of many rusts and particularly the sporidia are wind-borne, while the summer spores of the powdery and downy mildews are produced in such a way as to suggest this method also. The aecial stage of *Gymnosporangium*

macropus shows an interesting adaptation.[16] During dry weather the segments of the pseudoperidium are curved outward in stellate form but during humid or rainy periods they approach each other and partially or completely close over the spores. The spores are thus set free at a time when they are most likely to be carried away, and this is especially important in heteroecious forms which must reach the alternate host or fail to develop.

Judging from the results of experiments in the field it seems that the most prevalent spores belong to species of the imperfect fungi, and especially to the Hyphomycetes. Perhaps these facts are to be explained by the omnipresence of certain species of this group rather than to the fact that they are better adapted for wind dissemination. In the work carried out by Wolf only a single pycnidial form, Phyllosticta, was obtained during a long series of orchard tests. The work of Burrill and Barrett[17] on the wind dissemination of *Diplodia zeae*, the fungus causing dry rot of corn, may be mentioned in this connection. They found by field tests that spores of this fungus were carried by the wind and they attribute much of the infection to wind-borne spores from old stalks. There appears to be little direct experimental evidence to show to what extent ascomycetes which forcibly eject their spores from the asci are disseminated by the wind. In many cases the ejected spores are surrounded by a sticky material and *a priori* reasoning would suggest that in such cases they are not extensively carried by the wind. It is at least suggestive that the spores of ascomycetes are obtained so rarely in exposure plates in the open. Further investigations may show that ascospores are more generally scattered by the wind than present experiments show. It is the idea of the writer that wind-borne ascospores may be responsible for the spread of a fungus in the immediate environment, but that long jumps or wider dissemination are accomplished by other agencies than the wind.

The puffing of spores as in Peziza, Urnula, and other Discomycetes in which there is a simultaneous discharge of numerous asci, is undoubtedly an adaptation for wind dissemination. Since most of these fruits are produced close to the ground, the forcible expulsion of the spores must materially assist in their being car-

ried away by air currents. In the Hymenomycetes the forcible expulsion of the basidiospores from the sterigmata helps simply in liberating the spores from the sporophores, while the normal position of the hymenium makes the fall of the spores inevitable, and convection currents assisted by wind carry them away to more distant points.

Spores that are destined for wind transport may be set free in a cloud by the explosion of the fruit of the host plant. A beautiful illustration of this is to be found in the smut infected fruits of Oxalis, which burst and liberate the spores in much the same way that the capsules of touch-me-not expel their seeds.

DISSEMINATION BY WATER

Liquid water plays a very important part in the dissemination of some disease fungi. In certain groups of fungi free water is necessary for the development of some stage in the life cycle, that is, in those that produce active or motile spores, swarm spores, or zoospores. These active spores make their way for a shorter or greater distance from their point of origin as a result of their own power of locomotion. In other cases passive or inactive spores may be washed down from the host plant by rains and carried away by natural water currents or spread along the course of irrigation ditches.

The aquatic habit has been retained to a greater or less extent by the various species of the pond scum parasites, the water-molds, the white rusts and the downy mildews. The parasites of the pond scums are completely dependent upon free water for their dissemination and this appears to be equally true of some Chytridiales parasitic on seed plants. The natural habitat of the cranberry is particularly favorable for the development of the cranberry gall due to *Synchytrium vaccini*. It is also noteworthy that *Urophlyctis alfalfae* has made its appearances in this country in a number of regions in the Pacific coast country where alfalfa is grown under irrigation.

The Saprolegniales or water-molds include a much larger number of saprophytes than parasites and in the majority of forms are strictly aquatic in habit. Some species are parasitic on the eggs

and young of fish and also frequently gain entrance to the bodies of adults. While countless numbers of young fish and other aquatic forms annually fall a prey to the ravages of these fish molds, it is under the artificial conditions of the fish hatcheries, that the water molds are most likely to become epidemic. Not only may the water become filled with myriads of these motile spores of the water molds, but the diseased fish may transport the fungus for long distances and introduce it into entirely new localities.

There are two fungi which belong to the water molds that cause destructive plant diseases. One of these, *Pythium de Baryanum,* is the cause of a damping-off of seedlings, a great variety of species being attached. This fungus has attained practically a world-wide distribution. At just the periods that young seedlings are establishing themselves in the soil, this damping-off fungus finds conditions favorable for the development and dissemination of its swarm spores. These motile spores are able to swim actively in the soil water and are also spread by the spattering of rain and the meteoric water which flows over or through the surface layers of the soil. It is this production of enormous quantities of motile spores at times when the seedlings are young and susceptible that makes this one of the most destructive of the damping-off fungi. The other water mold referred to has been known to science only since 1906,[18] but when it first appeared in California it made such headway as seriously to threaten the citrus industries of that section of the country. The fungus in question, *Pythiacystis citrophthora,* causes the disease of lemons known as the brown rot, and the history of the discovery of the cause of this disease and of its method of dissemination forms one of the most interesting chapters in modern plant pathology. The natural habitat of the fungus is the damp soil of the orchard, and irrigation apparently favors its development. The spores of the fungus are not wind-borne and only fruit either in contact with the soil or very low down on the tree becomes infected. The motile spores can easily reach fruits in contact with the soil by swimming through the soil moisture, and the spattering of rain is supposed to carry spores to the lowermost fruits that are free from contact with the soil. If lemons were handled like apples in preparing them for the market, the brown

rot would never have become such a serious pest, but lemons must be washed or scrubbed, and it is just this process that makes a more extensive infection possible. Dirt bearing the fungus is transported to the washer on the surface of the fruits and the fungus finds in the water of the washer favorable conditions for its development. The washers thus become infected with the fungus and the water through which the lemons must pass becomes filled with myriads of the motile spores, some of which may gain entrance to the fruit during the washing and scrubbing process. Of course greater care is now taken in cleaning the washers and the use of fungicides in the water prevents the development of the fungus.

The Peronosporales, including the downy mildews and white rusts are not so completely dependent upon moisture for the dissemination of the spores, since their conidia (sporangia) are borne in such a way as to be carried away by the wind. They do, however, show a greater dependence upon moisture than many of the fungi that have abandoned entirely the production of motile spores. It is an especially noteworthy fact that the late blight of the potato, caused by *Phytophthora infestans,* is epidemic during wet seasons and is limited geographically by rainfall. This partial dependence upon free water for its development probably explains the reason the late blight has never been a serious potato disease in the drier portion of the plains country.

It is undoubtedly true that rain and water currents play a very important part in the dissemination of fungus spores. In the first place rain may assist in the further transport of wind-borne spores that have been lodged upon plant surfaces. In case of wound infections the spores may be finally carried into the wound by rain washing down over spore laden surfaces, the spores finally coming to rest in a more favorable position for germination. Many fungus spores are rarely carried away from the fruits in which they develop except through the agency of rain. This seems to be particularly true of many forms producing pycnidia surrounded by a more or less evident mucilaginous secretion which prevents their release from the fruit or their separation from each other except in the presence of sufficient water to dissolve the cementing substances. Such spores may accumulate as sticky or waxy masses

over the acervulus or they may be pushed out through the ostiole of a pycnidium as the result of growth of others within. In certain forms the extruded spore mass takes on the form of a long, coiled, flattened or cylindrical thread, which is designated as a "spore horn" or tendril. These sticky spores are produced in enormous quantities during warm, humid periods and the spore masses dry down and become hard if they are not washed away by rains. Many spores of this type retain their vitality for a considerable period as long as they are embedded in their mycelaginous secretion, but soon succumb to desiccation and other unfavorable factors as soon as they are separated by the rains.

In this connection several illustrations may be mentioned. *Valsa leucostoma,* the fungus causing die-back of peaches, plum and apricots produces conspicuous, brown or amber-colored tendrils which ooze out from the pycnidial stromata embedded in the bark. These are always abundant during the humid period following a rain, but disappear entirely except from especially protected positions during the first precipitation of any amount. During a warm rain the spores are being produced in enormous numbers but they are washed away as rapidly as they are extruded so the tendrils do not become visible until the rain has ceased. What has been said concerning the conidiospores of the die-back fungus applies equally well to those of the chestnut blight fungus, *Endothia parasitica.* It has recently been determined by experiments carried out under the writer's direction that the so-called summer spores are washed down from the blight lesions in enormous numbers, even during the winter rains when the temperature is but little above the freezing point.

There seems to be little evidence that the spores of bean anthracnose are wind-borne. The facts known concerning this disease indicate that rain and dew are of utmost importance in its spread after it has once been introduced by the use of infected seed. The fact that the spores of the Melanconiales are found so infrequently in the air lends support to the theory that these fungi are largely dependent upon rain and other agencies besides wind for their transport.

There is not much direct evidence to show the part of running

water in the transport of non-motile spores. If these spores fall into streams or irrigation ditches there is every reason to suppose they will be transported for some distance. In some forms germination would take place in a few hours, and so the possibility of transport for long distances would be excluded. It is claimed that irrigation water plays a very important part in the dissemination of the late blight of celery in California.[19] The spores may be washed away from the pycnidia and carried along the trenches with the irrigation water.

INSECTS AND DISSEMINATION OF FUNGI

The relation of insects to the spread of plant disease is a subject to which sufficient attention has not been directed. The numerous insect-borne diseases of man and animals suggests a similar relation between insects and plant diseases. In most insect-borne animal diseases the insect acts as an intermediate host, and is not simply a carrier as is true in the case of the "typhoid fly." Not a single instance of an insect acting as an intermediate host for a fungus causing a plant disease has yet been brought to light, but the part which insects play in the dissemination of fungi is limited by their work as carriers and as producers of wounds which make infection possible.

It seems probable that insects play a very important part in the dissemination of saprophytic fungi. Fungus fruits are in many cases rich storehouses of food, and insects have become mycophagists, either utilizing the natural growths or becoming cultivators of fungi as is exemplified by the "ambrosia" beetles, or the ants with their fungus gardens. In visits to fungus fruits insects cannot fail to carry away spores, in much the same way that insects carry away pollen (spores) from the flowers which they visit. In some cases there seems to be a definite adaptation to insect transport of spores, while in others the transport is apparently only accidental.

The carrion fungi, of which *Phallus impudicans* may be taken as an example, attract flies to their spore-producing surfaces by their characteristic odor. The greenish slime in which the spores are embedded also contains three sugars, levulose, dextrose, and

another intermediate between dextrose and gum. These and the spores are greedily eaten by flies. Fulton[20] has shown that flies transport the spores in millions by the adherence of them to their feet and proboscides, and also that the spores will germinate after they have passed through the digestive canal of these insects.

The sphacelia stage of the ergot of rye and other grasses gives a beautiful example of insect dissemination. The ovaries become infected at flowering time by wind-borne ascospores and the production of conidia soon begins. This production of conidia is accompanied by the secretion of a sweet substance, the so-called honey dew, which is eagerly sought by insects. A rapid dissemination of the fungus is accomplished since the visiting insects carry away spores and scatter them as they fly from flower to flower. Although the sooty mold of the orange and other citrous fruits is not a definite parasite, it becomes a troublesome pest. This fungus is associated with and spread by the white fly, or Aleyrodes and other species of aphid-like insects.[21] The secretions of sweetish fluid constitutes the pabulum which makes possible the development of the fungus. Some anther-inhabiting fungi are undoubtedly disseminated by insects. This is true of the smut of various species of the pink family. The affected anthers produce smut spores instead of pollen and these are carried from plant to plant by the visiting insects, thus assisting in the dispersal of the fungus.

The manner of spread of fire blight of the pear and apple was for many years more or less of a mystery. The bacteria causing the disease are set free upon the surface of the diseased parts in sticky droplets, and are quickly killed by exposure to sunlight and desiccation. Waite[22] first showed that the rapid spread of the disease during the spring is due to insects and especially to bees. The bacillus lives over winter in only a small percentage of the affected branches and is spread from these by insects. The blossoms become infected, the bacteria multiplying in the nectar, and thus the disease is spread from flower to flower by bees. Insects like leaf hoppers and others which bite the delicate young shoots are also important agents in the spread of fire blight.

An intimate relation between certain mites and the bud rot of carnations was established by the writer.[23] The mites are always

found in the buds that have been rotted by *Sporotrichum poae;* they find in the mass of rotted petals a most favorable substratum for their development. The young mites which migrate from diseased to healthy buds carry spores of the fungus with them and thus inoculate the healthy buds, their presence serving to accentuate the severity of the trouble.

The literature of plant pathology contains not infrequent reference to the part which insects play in the dissemination of plant diseases, but these are in many cases generalizations not based on direct experimental evidence. Murrill and others[24] have stated that the spores of the chestnut blight fungus are carried by insects, but up to the present date there are no published experiments which really substantiate this statement. It seems probable, however, that this early claim will be supported by experiments now in progress.

Massee[25] has pointed out the fact that the rapid spread of apple canker due to *Nectria ditissima* in England coincides with the introduction and spread of the "American blight or wooly aphis." He makes the following statement: "I think it would be scarcely an exaggeration to say that if we had no "wooly blight" we should have no "canker," that is in the sense of an epidemic. It should be pointed out, however, that this opinion which is not based on experimental evidence is not entirely acceptable. The whole problem of the relation of insects to plant diseases is one that merits more attention than has been given to it, and investigations in this line may be expected to yield important results.

DISSEMINATION BY OTHER ANIMALS

The prevalent notion in regard to the part which other animals play in the dissemination of disease-producing fungi is expressed by the following quotations:

"Insects, birds, snails and slugs are known to be unconscious agents in the dispersion of spores, whereas dogs, hares, rabbits, etc., running through a field of corn, potatoes or turnips act after the fashion of the wind by bringing into contact adjoining plants.[25]

"Mites, flies, birds, mice, etc., carry spores adhering to their

bodies from one place to another; and probably are frequently the unconscious cause of a new infection or the rapid spread of an epidemic due to fungi."

While the above are generalized statements based on but little experimental evidence this possibility has been demonstrated in some cases. Massee reports that snails and slugs are instrumental in spreading powdery mildews. Slugs allowed to crawl over mildewed leaves and then over healthy leaves left behind spores which soon caused the appearance of mildew along their pathway.

Birds, especially woodpeckers, have been mentioned by various writers in connection with the dissemination of the chestnut blight fungus. While the few tests reported to date (15) were negative it seems reasonable to believe that bird transport is a possibility. Woodpeckers frequently visit the chestnut blight lesions in search of insect larvae, and it will be remarkable if they do not carry away blight spores upon their feathers, bill or feet. While the writer is not yet ready to make any positive statement in regard to the part which birds play in the spread of this pernicious disease of the chestnut, a pertinent fact may be mentioned. By the employment of careful analytic methods a single hairy woodpecker has been found to be carrying as many as twenty different kinds of fungus spores. Johnson has suggested the possibility that the bud-rot of cocoanut may be carried by turkey buzzards as well as by certain insects and reports some experiments which seem to lend support to his contention.[26]

In considering this subject observations on and experiments with saprophytic fungi may be mentioned. Voglino[27] has shown that slugs eat the sporophores of fleshy agarics, especially the hymenium, and that the spores begin to germinate in their intestines and afterwards continue to grow in the ground in which the slugs burrow. The subterranean ascus-bearing tubers of truffles are sought as food by rodents and the spores of these fungi are supposed to be dispersed by this means.

Herbivorous animals play a very important part in the dispersal of certain dung-inhabiting fungi. A considerable number of these dung inhabiting fungi expel their spores with considerable force from the fruiting body. If it were not for the grazing ani-

mals these spores would in most cases, be carried no farther than the force of their projection would take them for they are sticky and adhere to the surface of the objects upon which they light. Foliage with attached spores is eaten by grazing animals and the spores being able to pass through the intestines of the animal unharmed, find a suitable substratum for their development at some distant point. Among those forms which have developed this habit the following may be mentioned: Pleurage, Ascobolus and other black-knot allies which shoot their spores by the explosion of the ascus; and certain Hymenomycetes like Coprinus and allies.

DISSEMINATION BY AGRICULTURAL AND COMMERCIAL PRACTICES

Numerous instances of the transport of disease producing organisms by man as a result of agricultural and commercial practices are known. With the development of our agriculture and the intercourse between nations the part of man in the dissemination of plant diseases has become more pronounced. The possibility of the spread of diseases and insect pests from one region to another has long been known and states have endeavored to safeguard the agricultural and horticultural interests of the people by laws relating to inspection of nursery and other stock. From the standpoint of fungus diseases this inspection has not been as effective as might be desired for in the majority of states the inspectors have been entomologists, familiar only with the more evident plant diseases such as crown-gall or black-knot, and not skilled in the detection and diagnosis of the more obscure troubles. This statement is not imaginary but is based on facts, for the writer has, in numerous instances, visited nurseries immediately after the official inspection and found various fungus diseases prevalent that were entirely overlooked. The demand for national legislation making restrictions which might govern the introduction of pests from foreign countries and the spread of troubles from infected regions to those free from the disease led to the recent passage of the Plant Quarantine Act.[28]

Fungi which are primarily soil dwellers may be carried by transport of soil. Spores which have not yet germinated may be

incorporated with the soil but in some of the most serious troubles the fungus is present in the mycelial or in the sclerotial stage. One of the agricultural practices that should be condemned on this account is the use of alfalfa soil for the inoculation of a field with the nitrogen-fixing bacteria. If, for example, the soil selected contained the mycelium of the alfalfa Rhizoctonia or that of the southern fungus of cotton root rot, these troubles might be introduced into new fields. We have reason for believing that the sterile mycelium of such fungi will endure considerable dessication without losing its vitality. The "spawn" of mushroom growers is but mycelium preserved and temporarily dormant in dried bricks of compost. It is particularly in the cultivation of plants under glass that we find the introduction of fungi and other pests with the soil. The drop or Sclerotinia disease of lettuce is one that persists by the development of sclerotia that may remain in the soil.[29] It seems to be true that root-knot of roses is frequently introduced into greenhouses by the selection of soil previously infected with eel-worms.

Some parasitic fungi are capable of passing one stage in their life history in the soil or in compost. This is especially true in the case of certain smuts, of which corn smut is a most notable example. It is a common practice on farms to feed corn fodder or stover to cattle and return the compost to the soil. The smut spores find in the compost especially favorable conditions for germination and also for the production of secondary sporidia in countless numbers by a process of budding. Compost originating from the use of smut-infected corn may thus contain billions of sporidia of smut that are returned to the soil of the corn field where they are ready to produce new infections. The work of cultivation and the movement of wagons and teams from one field to another may be responsible for the spread of disease producing organisms. It is undoubtedly true that the mycelium of the cotton root rot is extensively spread through the fields during the cultivation of the crop. It is claimed by Massee that club root, or the finger and toe disease of cruciferous plants, may be spread by soil adhering to cart wheels, tools, shoes, etc. The practice of allowing diseased plants, fruits or other products to fall to the ground

and remain there unmolested save for the work of nature's scavengers is a too common practice that favors the spread of disease.

The part which man has played and is playing today in the dissemination of plant diseases can not be overlooked. This is the inevitable result of our specialized agriculture and modern commercial practices, but the distribution of diseases by the importation of infected seed, nursery and horticultural stock, and the transport of various commodities, can and should be reduced to a minimum by the employment of all possible safeguards.

Many of our serious plant diseases have been brought to this country from Europe or other foreign countries, and we can point in turn to pests which have been transported from America to Europe and elsewhere. The influence of climatic and edaphic factors upon the development of disease in epidemic form must be taken into consideration. It is by no means certain that a fungus pest which has proved serious in one country will prove equally serious in another, but the existence of serious diseases in a country or region should be kept in mind, and importations of susceptible stock made with extreme care.

Commercial concerns, state agricultural experiment stations and departments of agriculture, and the United States Department of Agriculture are all importing seeds and plants from foreign countries, in the endeavor to find plants valuable for the trade or better suited to the agriculture of the country. If we reflect upon the nature of seed-borne fungi it must at once be evident that this wholesale importation of seed is bound to be a prolific source of the spread of disease. It is undoubtedly true that the black-leg of cabbage previously referred to was brought to this country by infected seed[6] and that potato wart recently reported from Newfoundland was introduced from England.[30] These are illustrations of recent importations and it was the discovery of this latter disease in this country that gave one of the strong arguments for the passage of the recent Plant Quarantine Act.

The shipment of nursery stock is frequently responsible for the appearance of diseases in hitherto uninfected territory. In the greater percentage of even well managed nurseries plant diseases of various kinds may be found in profusion, the massing together of

individuals favoring their development, but the neglected nursery is literally a pest house of plant diseases. The Pennsylvania Chestnut Tree Blight Commission has records of spot infections of blight that were traced to the planting of nursery stock that was diseased at the time of shipment. The diseases of nursery stock that are accompanied by easily recognized symptoms, may easily be guarded against by rigid inspection of all stock offered for shipment, and fumigation is a reasonable safeguard against the spread of many insect pests, but unfortunately some of the most serious diseases can be carried by stock which shows no indication whatever of its presence. One of the most striking examples of this is to be found in the case of the seedlings of white pine affected with the so-called blister rust.[31] The fungus causing this trouble has a period of incubation in the bark of nearly a year before it causes the characteristic hypertrophies, and for this reason inspection at the time of importation is but an imperfect insurance against its introduction. In such extreme cases the quarantine of infected regions and the restrictions of shipment of stock that might carry the disease is entirely justifiable. Diseases like the black-knot, peach leaf curl, orange rust of raspberries and blackberries, and many others that produce a perennial mycelium in the host may easily be transported by infected nursery stock, while there are many opportunities for the transport of resistant spores on the surface of florists' greenhouse stock or field-grown plants. Besides this, incipient infections of various fungi may be present in either herbaceous or woody plants, and entirely escape detection at the time of shipment.

The transport of various commodities such as hay, grain, packing material, fruits, vegetables, wood, lumber and any crude plant products must play a part in the spread of plant disease. With our diversified trade relations with foreign countries and the extensive trans-continental shipments of plant products from west to east and from south to north, opportunities for the transport of plant diseases over wide ranges of territory are greater than ever before in entire progress of our agriculture.

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THE PERIODICITY OF ALGAE IN ILLINOIS

By Edgar Nelson Transeau

The following notes on the periodicity of algal occurrence and reproduction are based on a study of collections made at intervals, at more than a hundred stations in East-central Illinois. They cover the period from January, 1908, to January, 1913. About half of these stations are in the vicinity of Charleston. These have been visited at frequent intervals, while those at a distance have been examined at critical times of the year as suggested by conditions at Charleston.

All collections have been preserved in a solution, a liter of which contains 100 cc. formalin, 300 cc. alcohol, and 600 cc. of water. Each collection is labeled and numbered in the field and as soon as convenient a 4 by 6 inch index card is labeled and numbered to correspond. On this is kept (1) a record of the weather conditions, water conditions, temperatures, relative abundance of algae in general, and whether floating or attached, etc.; (2) an analysis of the collection made in the laboratory, showing all algae present as far as identifiable. In the case of many only the genus can be given, together with measurements that might aid in determining them from later collections containing the same forms in a fruiting condition. In summarizing the work it is possible then to go back to cards or to the collections at any time and correct any errors or get any further data desired.

The waters of Eastern Illinois are rich in dissolved mineral matters derived from the prairie soils. For example, the water of the Embarras river near Charleston contains on the average .14042g. of soluble matter per liter. It is consequently not surprising that the algal flora should be large and varied. Its extent may be roughly indicated by the fact that the collections contain more than forty-five species of *Oedogonium,* and the genus *Spirogyra* is represented by at least thirty-five species and varieties. These numbers are considerably more than have been reported from Massachusetts

whose algae are better known probably than those of any state in the Union.

In order to get at the periodicity the card records have been listed by months for the five-year period. An examination of the resulting chart shows that on the basis of *their periods of greatest abundance, the duration of their vegetative cycles, and the times of their reproduction,* the algae may be divided into seven classes.

I. Winter Annuals. These are species which begin their vegetative cycle in the autumn, increase up to the time the ponds are frozen, and last over the winter under the ice. During protracted winter thaws—which usually occur in January—they may develop further and even fruit. Their period culminates in March and April. Sexual reproduction may occur at any time from November to April. Zoöspores are formed from the beginning through the period of increase. Aplanospores and akinetes develop mostly during the period of decline (Fig. 1). Some local examples of

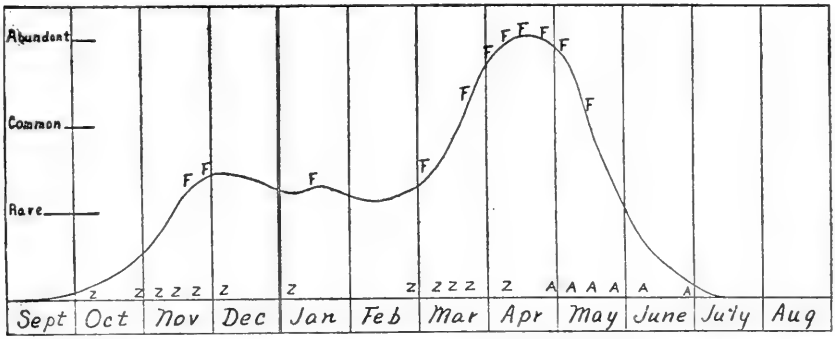

Fig. 1. Frequency curve of winter annuals. In this and subsequent figures the probable occurrence of sexual reproduction is indicated by F, zoospore reproduction by Z, and the formation of aplanospores or akinetes by A.

algae belonging to this type are *Vaucheria geminata, Vaucheria sessilis, Draparnaldia plumosa, Tetraspora lubrica,* and *Stigeoclonium lubricum varians.*

II. Spring Annuals. These are forms in which the vegetative period begins in late autumn or early spring, culminates in May and declines in June. Sexual reproduction occurs in April, May, and June. Zoöspores are formed mostly in early spring, and

aplanospores and akinetes during the period of maximum abundance and decline (Fig. 2). This type includes the largest number of

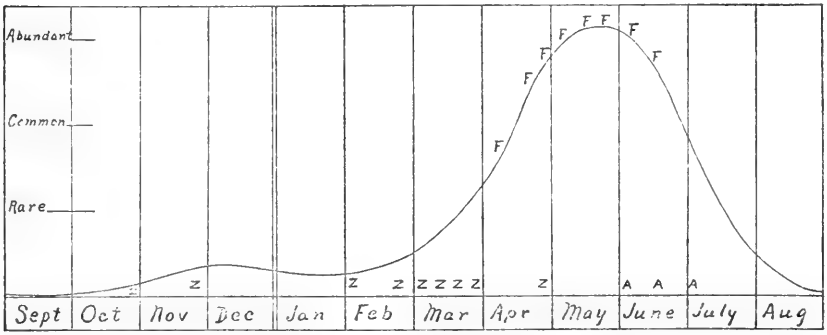

Fig. 2. Frequency curve of Spring Annuals

species, among which are *Spirogyra varians, Spirogyra Weberi, Zygnema stellinum, Oedogonium rufescens,* and *Ulothrix variabilis.*

III. Summer Annuals. The vegetative period of the algae of this class begins in early spring and culminates in July and August. The decline is gradual and extends through the autumn months. Sexual reproduction occurs in July, August and September. Zoöspores, when formed, are most abundant in Spring and early Summer. Aplanospores develop mostly in August and September (Fig. 3). Among the local examples of this class are

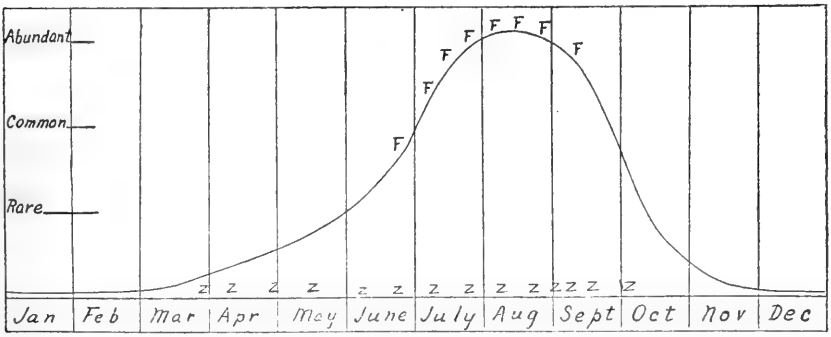

Fig. 3. Frequency curve of Summer Annuals

Spirogyra decimina, Spirogyra maxima, Schizomeris Leibleinii, Calothrix stagnalis, and *Oedogonium Vaucherii.*

IV. Autumn Annuals. These species begin their vegetative development in late spring, increase through the summer and have their period of maximum abundance in the autumn. They may disappear at the time of freezing up of the ponds, or gradually through the winter. It has been noticed in at least one instance, *Spirogyra setiformis,* that when the freezing occured at the time of fruiting, a large part of the filaments still in a vegetative condition remained over the winter and completed the fruiting in the early spring. This is indicated in Fig. 4 by the dotted line. The sexual reproduction

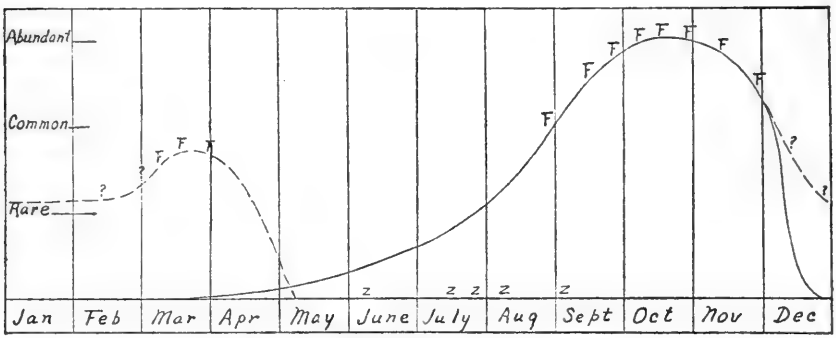

Fig. 4. Frequency curve of Autumn Annuals

usually occurs during September, October, and November. Among the algae of this class are *Spirogyra nitida, Rivularia natans, Oedogonium crassum amplum, Spirogyra setiformis,* and *Oedogonium obtruncatum.*

V. Perennials. This group includes forms in which the vegetative cycle goes on from year to year without interruption. The algae may become very scarce during unfavorable periods but they are capable of at least maintaining themselves without the production of reproductive bodies. They commonly attain their greatest development during the summer and early autumn. Sexual organs are mostly produced in late spring or early autumn—sometimes in both. Zoöspores are most abundant in spring and summer,—not infrequently they are also produced in autumn (Fig. 5). *Cladophora glomerata, Rhizoclonium hieroglyphicum, Pithophora oedogonia, Pleurococcus vulgaris,* and *Oedogonium grande* belong to this class.

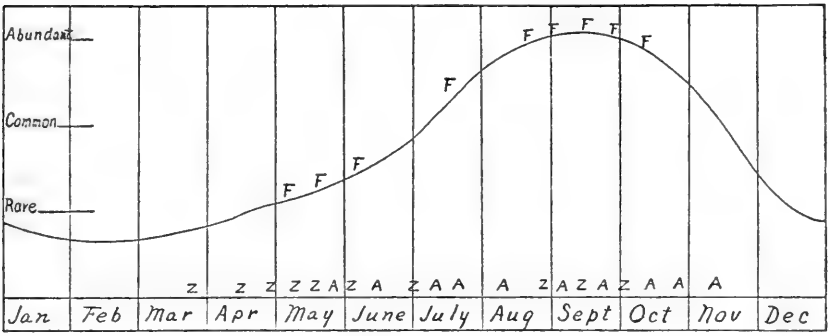

Fig. 5. Frequency curve of Perennials

VI. Ephemerals. These species have very short vegetative cycles, usually best reckoned in days—at most in weeks. Generations succeed one another rapidly through the periods of favorable conditions. Also because of varying capacities to respond to environmental conditions the generations overlap. It is therefore difficult to represent this group by a curve or collection of curves. Figure 6 is an attempt to represent it in general. It must be re-

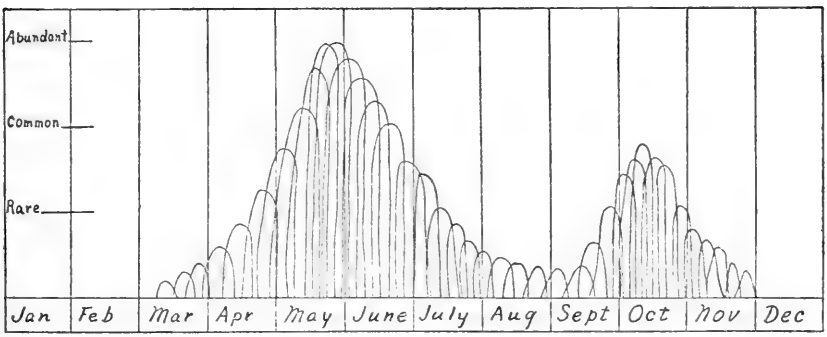

Fig. 6. Frequency curves of Ephemerals

membered that the lengths of the curve for a generation will vary in the different species and under different conditions of temperature, moisture and illumination. The species are mostly soil-surface and plankton forms. Few of them reproduce sexually. Zoöspores, aplanospores and akinetes are the usual means of increase, dissemination and passing an unfavorable period. The soil

forms are favored by wet weather. All the forms may be found in greater or less abundance in all but the winter months. Among the commoner local Ephemerals are *Botrydium Walrothii, Scenedesmus quadricauda, Pediastrum Boryanum, Vaucheria terrestris,* and *Ineffigiata neglecta.*

VII. Irregulars. In addition to the above six types of periodicity there is a group of forms for which the combinations of environmental conditions necessary to induce marked vegetative development or bring about reproduction do not occur with seasonal regularity. The period between maxima may be of more or less than a year's duration. Because of their uncertainty it is difficult to discover them in a five year collecting period. There is always the danger that they might have been overlooked during the first year or two when my collections were not so thoroughly representative as during the last three years. I will therefore venture but a single example: *Oscillatoria princeps,* for which I have a fairly satisfactory five-year record. This alga has been exceedingly abundant at times in one of the ponds from which I have collections at short intervals. These periods of maximum development have occurred without seeming reference to season—aside from absence during the winter.

The diagrams for the several classes of periodicity show their own relative abundance during the different months of the year. The classes, however, do not represent equal parts of the algal vegetation of this region. In Fig. 7 I have attempted to show the relative importance of these several classes. For reasons already stated the Irregulars are not included. One reason why the group of Spring Annuals is of such great importance is that the variety of habitats at this season is vastly greater than at any other period of the year. Habitat diversity and algal variety both have their minimum during late July and August. Fig. 7 also indicates the approximate composition of the algal flora at any time of the year. Thus in October the Perennials and Autumn Annuals constitute the bulk of the forms, with some remnants of the Summer Annuals, some Ephemerals, and some early stages of the Winter Annuals.

With regard to periodicity in general it must not be forgotten, that the classes observed in one locality do not necessarily occur in

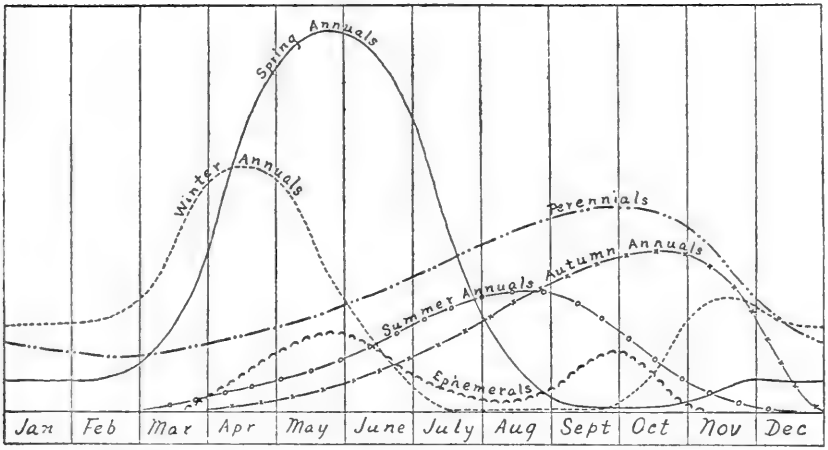

Fig. 7. Estimated relative importance of the several types of algal periodicity, and the composition of the algal flora at any time of the year. This leaves out of account the irregulars.

all others. Indeed, I have good reason to believe that farther north the number of classes is reduced and that two or more may become merged into one. Judging by the publications of Fritsch, in England many of the forms which occur here as winter annuals attain their maximum development there in the summer. Hence we may expect to find considerable local variations in the floristic composition of the periodicity classes.

There is a notion prevalent in the text books and laboratories that algae produce sex organs more abundantly during the low water stages. This is sometimes expressed by saying that we may look for sexually reproductive material when the water begins to concentrate, or "when the conditions become hard enough," whatever that may mean. Or it is said that they remain in a vegetative condition so long as the waters are high. That the opposite of this statement is true was strongly indicated by an examination of my records at the end of my first two years of collecting. In the three years that have since ensued I have watched this particular point with much care, and there can be no question that in this region at least (1) the greatest number of species fruit sexually, (2) a particular species fruits most abundantly, and (3) when a species produces more than one kind of spore, the greatest variety of spores

occur during periods of high water. The spring of 1912 was a period of heavy rainfall. The remnants of old prairie ponds along the railroad rights-of-way contained fruiting algae in quantity and variety beyond anything seen during the preceding four years. The high water-level was maintained until after the spores were mature. On examining the corresponding collections for the spring of 1911 I find what are probably the vegetative filaments of many of these same forms, but only a few produced spores. Again, the autumn of 1911 was one of exceedingly high water,—the rainfall of September being more than three times normal. Coincidently a number of species which I had before found fruiting only in the spring, developed and fruited before the pools froze. These algae fruited again in the spring in some of the same pools. Whether the filaments developed from the spores of the preceding autumn, or from spring spores which failed to germinate in the autumn it is impossible to say. But the fact of importance is that the continued high water of the autumn of 1911 was attended by increased fruiting of algae.

The origin of the prevailing notion that algae fruit during low water stages may be connected with the fact that such a large number of algae fruit in late spring when the rainfall is decreasing and the water levels are lowering. This is a coincidence of the lowering water level with the time of fruiting and there is no causal relation between the two. If the weather conditions are such that the water level does not fall at this time of year, but remains constant or rises the fruiting will not only take place but its amount will be increased.

Fig. 8 shows the number of species known to have fruited either sexually or asexually during each month for the years 1911 and 1912. The years are also divided into seasons and the total number of monthly records per season is indicated in the second line from the bottom. In the last line is given the water level, as shown by Weather Bureau records of rainfall, and my own notes. It should further be noted that the seasons during these two years are exactly opposite in so far as rainfall and water levels are concerned. Leaving out of account the temperature conditions which at most are of secondary importance, we have here a basis for direct com-

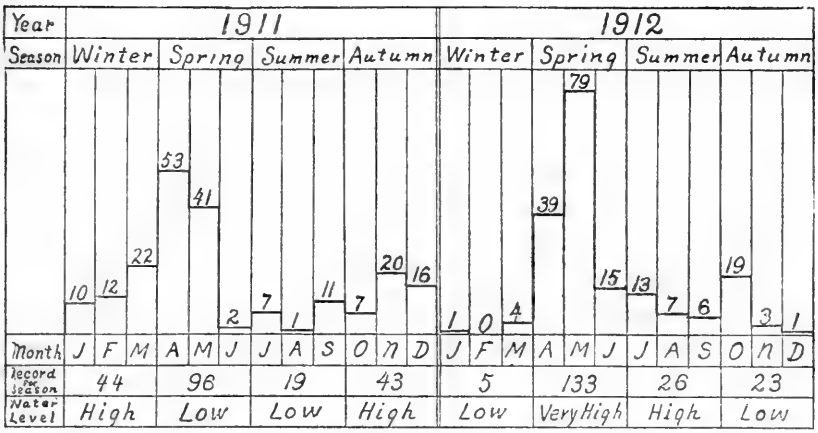

Fig. 8. Number of monthly fruiting records (both sexual and asexual) grouped by seasons and compared with the water level. It will be noted that for each of the seasons the conditions were opposite in these two years. Note correlation between high water level and increased fruiting.

parison of wet and dry seasons. The close correlation between high water level and increased fruiting is too obvious to need further comment. The only record which shows a marked temperature influence is the one for the winter of 1912. There was not the usual thaw in January and February, which would bring this number nearer the winter mean.

Another notion prevails that sexual reproduction is confined to the time of maximum vegetative development. While it is probably true of a majority of algae, I wish to call attention to the fact that there are many exceptions. When a more detailed report of these collections can be made, there is reason to believe a list of considerable length will show that many algae may reproduce sexually at any or all stages of their vegetative cycle. In other words vegetative development may follow sexual reproduction or may go along with it, as well as precede it.

The failure of algae to fruit in streams has been mentioned by numerous authors. Klebs and Oltmanns speak of the Vaucherias, and Fritsch speaks of the Spirogyras. For eastern Illinois I can record the fact that all the species of *Vaucheria, Spirogyra* and *Oedogonium* known to grow in our streams have been collected at

one time or another in fruit. I do not, however, doubt the accuracy of the European observations. Our streams possibly are more sluggish and perhaps there is a chemical difference of importance. The flowing water is generally supposed to retard fruiting by furnishing improved vegetative conditions. Hence we should expect a retarding effect on fruiting which would show clearly in the relative time of fruiting in ponds and streams. On going over the records for species which have been collected in fruit in both situations I find that the stream record is likely to be simultaneous with, or precede, or follow the pond record. As far as I have studied the records there is no evidence of a retarding effect of running water. There is abundant evidence to show that the number of possible combinations of external factors that will produce sexual reproduction is very much less than the number that will induce zoöspore production. Zoöspores may be formed at short intervals throughout the life cycle while the sex organs usually develop at a definite time. The formation of non-motile spores in *Pithophora* seemingly occurs under any and all conditions. This represents the one extreme. At the other is *Zygnema pectinatum* which produced aplanospores but once in the five years and then they were common wherever the *Zygnema* was found.

It seemed best to the writer to await the completion of the examination of the collections before attempting to discuss the literature and the details connected with this problem of periodicity. The names of the green algae used in this paper correspond to those found in Collins' "Green Algae of North America."

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SUMMARIES IN MICRO-BIOLOGY

For some months the Secretary has been planning to secure for this Journal and its Department of Summaries, a series of papers from biologists dealing with the chief groups of microscopic plants and animals. It has not been the purpose to present a complete survey of any of the groups. The wish has been rather to bring together in one article a statement of the following things:—general biology, the method of finding, the methods of capture and of keeping alive and cultivating in the laboratory; how best to study; the general technic; the most accessible literature; and a brief outline of the classification, with keys for the identification of at least the more representative genera and species of the micro-organisms likely to be found by the beginning students in the United States.

It has been felt that the getting together of such data as this, while not a contribution to science, would be a contribution especially to isolated workers and to teachers and students in the high schools and smaller colleges.

Papers have already appeared treating the aquatic Oligochetes and the Melanconiales. The following is the third paper of the series. It is proposed to have such synopses from time to time until the more common American species of such groups as the following have been covered: The Blue-green Algae, Conjugating Algae, Diatoms, other Green Algae, Zygomycetes, Downy Mildews, Yeasts, Powdery Mildews, Hyphomycetes, Smuts, Rhizopods, Infusoria, Turbeliaria, Bryozoa, Water Mites, Entomostraca, etc.—[Editor.]

THE NATURE AND CLASSIFICATION OF PLANT RUSTS

By Frank D. Kern

1. Introduction.

The rusts are small, mostly microscopic fungi, parasitic in the tissues, especially the leaves, of the higher plants. They belong to the order Uredinales (or Uredineae) which contains without doubt the largest array of forms of any order of parasitic fungi. There is an extensive economic interest in the rusts because of the fact that they do great damage to most of the cultivated crops. Their varied spore-formation makes them at once of unusual interest to the general student with the microscope. Many species have spores of five morphological sorts. In some species these occur in regular succession upon one sort of host-plant but in many there is a striking change of hosts (known as heteroecism), a definite part of the life-cycle being produced quite apart and dissociated from the other part.

The spores are borne in more or less definite groups called sori (rarely singly), covered at least at first by overlying host tissue and set free either by early rupture or by weathering. On account of the fact that the mycelium is always wholly buried within the host

tissues it is quite natural to fall into the habit of thinking and speaking of the spore-structures, which manifest themselves upon the surface, as if they constituted the whole plant instead of representing only the reproductive portions. Although it is true that this treatment will confine itself chiefly to the spore-structures yet it is well to get the conception at the start that we must look upon the mycelium with its resulting spore-forms, in its entirety, if we would compare these little organisms with other and higher plants.

On account of the vast array of these forms, many of which have never been investigated by anyone, it is manifestly impossible to present much in the way of description of specific forms. It is hoped, however, that a statement of the main features of morphology and life-history together with their application to classification may serve to break down some of the apprehensive feelings which many now entertain toward the group as a whole. It is with this object in view that the following discussion is presented. The systematic account is confined to genera and species found in the United States.

2. Habitat and Distribution.

The rusts are strictly parasitic upon ferns and flowering plants and are liable to be found anywhere upon these hosts. Although the spores are microscopic in size, when aggregated into sori they are often conspicuous even to the naked eye and can usually be recognized easily under a hand lens. The sori may appear upon any part of the host above ground but the leaves are most commonly affected. Presence of rust may often be indicated by yellow or discolored spots upon the leaf-blades, or by swellings and galls upon the petioles and stems, or by fasciations of the branches known as witches' brooms.

In consistency the sori may be powdery (pulverulent), from the falling away of the spores, or they may be compact and firm, or in some species gelatinous. In shape and size there is great variation. Often they are roundish or oval, about 0.2-1 mm. across and more or less cushion-shaped (pulvinate); some are cup-shaped (cupulate), 0.1-0.4 mm. in diameter; others project as cylindrical, filiform, columnar, or wedge-shaped masses varying in length from 2 or 3 mm. up to 10 or 20 mm. In practically all cases the spore-mass is elevated to some extent above the surface of the host tissue and by

this means alone it is often possible to distinguish in the field between true rusts and many spot-fungi which simulate rusts in general appearance. This is especially true of grass and sedge rusts. In color the various shades of yellow and brown predominate, but some are so pale as to appear almost white, while many are dark enough to be called black.

Rusts attack plants in all sorts of physical and climatic conditions from the seashore to the summits of the highest mountains, and from the tropics to the polar regions. There is scarcely a family[1] of flowering plants in which some of the members are not affected by these parasites. In most any region where there is vegetation some rusts can be found. In the fields on wheat, oats, and other cereals; in the orchards on apples, pears, and quinces; in the gardens on asparagus and beans; in the ornamental plantings on roses, hawthorns, and cedars; in greenhouses on carnations and chrysanthemums; in the forest on pines, spruces, firs, oaks, cottonwoods, and willows; in low places and swamps on sedges and crowfoots; in semi-arid regions on sage-brush and greasewood; in wild and waste places everywhere on grasses, sunflowers, asters, goldenrods, dandelions, and hundreds of other weeds and flowers.

Because a rust is known to live upon a certain host it does not necessarily follow that the rust can be found wherever the host grows. Wild roses have several species known on them; one of these is found practically everywhere throughout the region of the hosts, while the others seem restricted to certain geographic locations, for example one is in the northeastern states, another in the prairie region of the central west, another in the Rocky Mountains and so on. Some rusts which change hosts, as indicated in a foregoing paragraph, might be expected to be limited to the region which is common to both hosts, but the fact that many of these have the capacity to maintain themselves independently on one host upsets this expectancy. A notable illustration of this is the common stem-rust of wheat which can have one stage on the barberry if any bushes are in proximity but which flourishes equally well in regions where the barberry is unknown.

1. The order Pandanales, of which the cat-tail (*Typha*) is our representative, and the Palmales, the palms, are conspicuous examples of large alliances upon which no rusts are known.

It becomes evident from the foregoing discussion that in a study of these fungi a study of the hosts is also not only important but necessary. A knowledge of the hosts is essential in classification and identification. A good way to begin is to examine and become familiar with all of the forms of rust on some particular host or closely related groups of hosts. In that way an interesting knowledge of flowering plants will be built up as the study proceeds from one group to another.

3. Collecting.

In collecting one keeps the eye on practically all of the vegetation, looking especially for discolored spots and swollen (hypertrophied) areas but does not fail to take hold of and examine closely many a plant which appears perfectly normal. A leaf or shoot which is more upright than usual is always suspicious. A hand lens is very useful and may assist greatly in forming a judgment as to whether a rust is present. Until one becomes familiar with the gross appearances of the various sori it is well to take home questionable material for microscopic examination.

It is always best to gather a fair amount of material. The importance of gathering sufficient to give some clue as to the identity of the host after the specimen has been preserved and packeted cannot be over emphasized. Flowers or some portion of the infloresence should be included whenever available, portions of the stem, unrusted leaves, basal leaves, etc., are advantageous. Care should always be taken to make sure that the rusted specimens and the portions included for host identification are from the same plant, or species, otherwise some very curious results may be obtained. Such a warning may seem unnecessary but such things have happened to experienced collectors. Some make it a point to gather separate phanerogamic specimens for the host determination but such is not necessary as a rule and is less convenient than the inclusion of smaller diagnostic portions of the host to be included with the fungous specimens.

4. Care and Cultivation.

If specimens are desired for future study only they do not require any special treatment but are best preserved by pressing

them in the ordinary method between some sort of absorbent driers. If it is desired to keep the spores alive so that they may be germinated and studied, or used for inoculating purposes, then certain precautions are necessary.

In general we may divide the spores into two classes, active and resting. The *active* class includes the cluster-cup spores, the summer or red-rust spores, and certain others such as those of the common cedar-apples. These spores are ready for germination upon maturity and will lose the power to grow unless kept in a reasonably fresh condition. If it is desired to keep them alive the parts of the host upon which they are growing should be kept as near normal as possible. In the case of small herbaceous plants often the best way is to remove them to pots, taking care to transfer a sufficient ball of earth so that the shock of transplanting will be reduced to a minimum. Oftentimes portions of the host-plant may be kept fresh for a sufficient time by placing the cut ends of stems or branches in water.

The winter or so-called black-rust condition of grass and sedge rusts furnish fine examples of the *resting* class of spores. These spores are produced in the late summer or fall and normally retain their viability through the winter and germinate in the spring. Collections made in the fall and kept in a warm dry room during the winter usually fail to germinate. The freezing temperature of the outdoor atmosphere is not detrimental. It is necessary to prevent the specimens from thoroughly drying. If put up in cheese cloth packets and tied to the branches of a shrub close to the ground the spores will usually winter over well. Resting spores collected in the field in the early spring usually show good germination. In the spring the cloth packets should be brought into the laboratory about the time conditions are favorable for growth outside. The packets may be sprayed and after a few days of warmth and moisture the spores should show signs of growth.

Germination can be nicely observed in a hanging drop culture. Ordinary tap water is used for the hanging drop. If care is taken to make the drop rather shallow it will be possible to focus with the ordinary high power. The time required for germination depends upon the conditions in which the material has been kept. The

germ-tubes may begin to show up in an hour or two. A drop culture which does not show germination in twenty-four hours may as well be discarded.

If it is desired to make an inoculation indoors some small vigorous potted plants must be available. In case it is desired to carry out such an experiment indoors for demonstration purposes it is necessary to know the species with which one is dealing in order to attempt the inoculation upon the right species of host or else the results would be very uncertain. For example there are about one hundred species of rusts on grasses in North America. It is certain that they all produce cluster cup stages on various broad-leaved plants, but the life-histories of more than half of them are still unknown. If one is conducting an investigation many trial inoculations are attempted and some of them occasionally meet with success, but for demonstration one must select forms which can be expected to produce success. A few suggestions may not be out of place here.

The black-rust spores from the stems of wheat will infect the leaves of the barberry (*Berberis*). Young barberries may be grown in pots from seeds. The grayish-black rust from the leaves of oats will inoculate the buckthorn (*Rhamnus*), which may also be grown easily from seeds. The sunflower rust does not change hosts and the spores from the dark brown sori on wintered over leaves may be transferred to young sunflower plants and will produce there the cluster-cup stage. Spores from the common large cedar-apple on the red cedar will produce abundant infection on the wild crab-apple or the cultivated apple.

For indoor experiments the spores are removed from the grasses with a knife or scapel blade and applied to the moistened leaves of the trial host. In the case of the cedar rust it is not necessary to apply the spores but merely to suspend the cedar-apple over the plant. A moist surface and a saturated atmosphere are necessary factors for the germination of the spores. In order to insure these conditions the plant is sprayed with an atomizer before the spores are sown, the parts which will not dampen being rubbed with the fingers until water will adhere. After the sowing is made the plant is placed under a bell-jar and set in a shaded position for

two or three days. The bell-jar is temporarily removed each day to permit a change of air and is sprayed on the inside with an atomizer before being replaced.

After an inoculation is made an incubation period of about a week or ten days will elapse before infection will be evident by the appearance of sori on the areas where the spores were sown. This period must be taken into account if a teacher desires to have a demonstration ready at some given time.

5. Methods for Study.

The spores of practically all species of rust make excellent objects for microscopic study by simply mounting them in a drop of water on a slide and adding a cover glass, without any treatment whatsoever. It makes little difference whether the spores are fresh or whether they are from dried specimens they will as a rule make a good mount in water. It is even possible to allow a slide to dry out and then to run water under the cover glass and secure very good results. Distilled water is preferable to tap water.

Sometimes when spores are quite old and dry they do not wet up easily or appear somewhat shrunken. A good treatment in such cases is the addition of a little lactic acid to the drop of water. This will cause the spores to round out and take on a normal rotund appearance without producing any appreciable swelling.

On account of the ease and satisfaction in making spore mounts as described in the foregoing paragraphs it is rare that there is any occasion for attempting permanent mounts of spores. For purposes of studying the structure of the sori it is often desirable to have sections and very beautiful results can be obtained by fixing fresh material, embedding in paraffin and proceeding in the ordinary way, no special precautions being necessary. It is possible, however, to secure good preparations without resorting to the cytological methods. With some practice many will find it possible to cut good free-hand sections in pith. If the specimens are dry a small portion containing the sori is soaked in very hot water—if the water comes to a boil it will do no harm. Pith soaked in alcohol is preferable to dry pith. The pith cylinder is partially split to allow the insertion of the material and then, with some water on the razor blade to float the sections, all is in readiness. The sections can be removed

with a needle or sharp wooden pick to a slide and are ready at once for microscopic examination.

6. Characters that may be used in distinguishing the species.

In the classification and identification of the rusts there are three features which are of importance (1) the microscopic character of the spores and sori, (2) the life-cycle, i. e. the number of stages in development, so far as it can be made out, and (3) the name and systematic position of the host. The first can be learned from the microscope; the second cannot always be made out, but after a little practice helpful inferences may often be drawn; while the third must depend upon the familiarity with the flowering plants, the ability to work them out, or to secure competent aid.

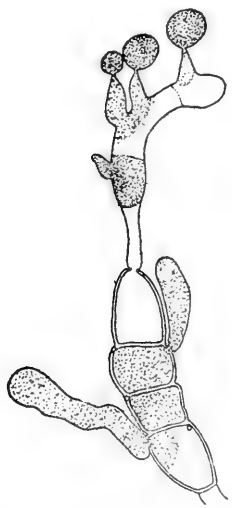

Fig. 1. A teliospore in process of germination. Two of the lower cells have young promycelia, the uppermost cell has a well advanced promycelium. This one shows the division into four basidia, three of which are shown forming basidiospores.

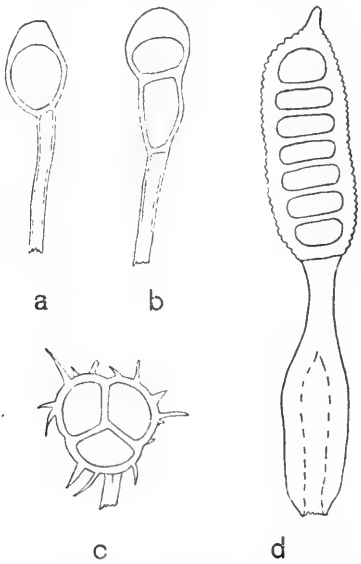

Fig. 2. Different types of free, stalked teliospores: (a) 1-celled, the wall smooth (*Nigredo Polemonii*); (b) 2-celled, the wall smooth (*Dicacoma Grossulariae*); (c) 3-celled by oblique septa, the wall spinous; (d) several-celled by transverse septa, the wall verrucose, the pedicel swollen (*Phragmidium subcorticinum*).

The rusts usually have more than one spore stage, the differ-

ent stages or phases appearing in a definite sequence and collectively referred to as the life-cycle or life-history. Of the five morphological sorts of spores mentioned in a foregoing paragraph only four are borne in sori on the host, the fifth being of a secondary nature produced upon the germination of one of the other forms (see Fig. 1). This fifth sort, known as a basidiospore because it is produced on a basidium, is important in indicating the relationship of the rusts to other fungi but is of no importance in identfication. The basidia themselves are of importance, especially as regards their formation whether within or without the spore.

Of the four sorts of spores borne in sori only one is common to all species, this one (together with the basidiospores) comprising the full life-cycle in some species. This stage which is never lacking in any life-history is known as the *telium* (plural *telia*) and the spores as *teliospores,* sometimes called also teleutospores, and represented by the symbol III. The teliospores may be 1-several-celled (see Fig. 2), the wall may be smooth or rough but is not in any known species set with prickles (echinulate). Upon germination the teliospores produce the secondary basidiospores, which upon successful infection usually produce the *pycnial* stage, the sori being known as *pycnia* or often as spermogonia. The pycniospores are functionless so far as known and do not produce infections, but the presence of this stage is often of value in determining a life-cycle. Depending upon the life-cycle the rusts

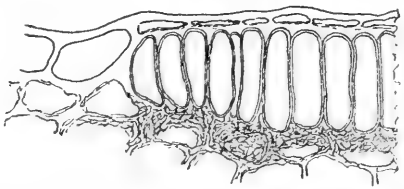

Fig. 3. A vertical section through a portion of telium which shows a single layer of spores compacted laterally. The sorus is subepidermal and the flattened epidermis is shown extending over the spores. The species represented is *Melampsora Medusae* on *Salix.*

may be divided into two groups, one with a short cycle and the other with a long cycle. In the short-cycle forms the mycelium from a basidiospore produces pycnia which are followed at once by teliospores or sometimes there is a suppression of the pycnia. The

pycnia usually appear as honey-yellow specks at first, often becoming blackish with age. The stage is often designated by the symbol O.

The long-cycle forms have the *pycnia* and *telia* and in addition have between the two either *aecia* or *uredinia* or both produced, in the order named. These two additional stages form important parts of the life-cycle.

The *aecial* stage is the so-called cluster-cup stage, deriving that name from the fact that each *aecium*, or aecidium, is in many species provided with a covering (peridium) which later opens out into a cup-like receptacle enclosing a mass of spores. The edge of this peridium often becomes toothed or fringed. In some forms the peridium becomes long and cylindrical while in others it is entirely lacking. Sometimes the aecia are encircled by clavate or capitate structures known as paraphyses (see Fig. 4, b). The aeciospores are usually borne in chains, are always 1-celled, the wall is roughened with more or less evident roundish warts (verrucose), and is in many species colorless. The symbol for the stage is I.

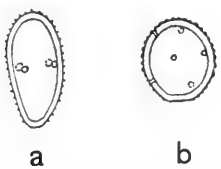

Fig. 4. (a) Showing the surface sculpturing on the side wall (longitudinal radial) of a peridial cell of *Gymnosporangium globosum*. The different species differ in the character of the markings. When in place in the peridial tissue other cells are joined end to end and side by side. (b) Showing the general nature of a paraphysis. These structures surround the spore groups in some species and in others may be intermixed with the spores.

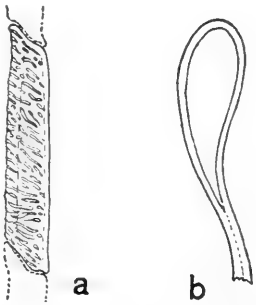

Fig. 5. Two types of urediniospores: (a) an ellipsoid spore with echinulate walls and four equatorial germ-pores (*Dicaeoma poculiforme*); (b) a globoid spore with verrucose walls and six scattered pores.

The *uredinial* stage is the one often popularly referred to as the red rust stage. In most genera the *urediniospores* (see Fig 5), or uredospores, are borne singly on pedicels in naked sori, but in some they are in chains and may be surrounded by peridia or by paraphyses. The walls of the spores are usually colored and are

always rough, either echinulate or verrucose. The spores are single-celled. Functionally these spores are repeating spores, i. e. they may reproduce themselves over and over indefinitely. The symbol for this stage is II.

The microscopic spore-characters most used are shape and size, surface markings, color and thickness of walls. In the case of teliospores the number of cells is important as is also the shape, size, and color of the pedicel which often remains attached. With regard to the urediniospores the number and location of the germ-pores are often of great value. These pores appear as lighter circular areas about 1-1.5μ in diameter and as they are the places through which the germ-tubes penetrate they are called germ-pores. The lactic acid treatment will usually assist in bringing them out more clearly than water alone. In some groups the characters of the peridial cells must be observed, especially the surface markings (see Fig. 4, a). The fine and varied character of the surface sculpturing on some of these cells almost makes them rank with diatoms as objects of microscopic interest.

7. Topics for Investigation Suitable to the General Student of the Group.

The rusts form an interesting group in which much remains to be done in the United States. One of the most fascinating and at the same time profitable opportunities for botanical students everywhere is to institute a careful study of heteroecious forms. Heteroecious species are divided into two wholly unlike halves and actual culture (inoculation) experiments are necessary to prove a relationship. In order that the work of connecting the halves may go on expeditiously, with as little unprofitable labor as possible, it is essential that the experimenter be guided by some ideas of probable relationships. These ideas can be gained in the field. The finding of aecial and telial stages in close proximity in the field is, to be sure, not proof of their affinity but is a bit of prima facie evidence. The closeness of the association, the abundance of the infection, and the occurrence of known forms must all be taken into account. Observations can best be begun in the early spring when new growth is starting. To find a tuft of grass or sedge covered with wintered over teliospores in contact with some new shoots

of a broad leaved plant bearing aecia is a strong suggestion of genetic relationship. Since in North America there are about one hundred aecial forms whose relations to telial forms are unknown it will be recognized that there is abundant opportunity for field observations. The problem may be stated from the other viewpoint by saying that there are scores of telial forms whose relations to aecia must exist but are unknown.

Some observers without greenhouse facilities may like to verify their clues by means of actual cultures. It is often possible to obtain very satisfactory results by means of outdoor cultures in a garden or other protected place. Much valuable work has been done in this way. For example, plants known to bear aecia can be transplanted to the garden and cared for until they establish themselves. During the winter rust on grass suspected of being related can be placed over the ground so that the young shoots will have to push up through it. In this way results may be obtained early before the danger of stray infections is so great. If more than one such experiment is tried in the same garden much care must be observed to prevent cross infections which might lead to confusion.

8. Systematic (General).

Teliospores compacted laterally into flattened, cushion-like masses (see Fig. 3), or filiform, columnar masses (rarely solitary within the tissues), without stalks.

Walls of teliospores gelatinous, especially at apex, dividing internally into four basidia. Family 1. Coleosporiaceae.

Walls of teliospores firm, without internal division of contents. Family 2. Uredinaceae.

Teliospores free (see Fig. 2) or united in bundles, stalked, the walls firm, or with an outer hygroscopic layer. Family 3. Aecidiaceae.

Some authors include the first two families in one under the name Melampsoraceae, and use the name Pucciniaceae for the third instead of Aecidiaceae as given above.

9. Systematic (Special).

FAMILY 1. COLEOSPORIACEAE

This family contains only one genus of importance, *Coleospor-*

ium, with about 24 species. The genus has all four spore-stages. All the species are heteroecious, the aecia being the blister rusts on the leaves (not on the twigs or bark) of pine trees (*Pinus*). The uredinia are yellowish and powdery; the telia form waxy cushions; the teliospores germinate upon maturity in the fall and the internal division of the contents into four basidia can generally be observed with the microscope without difficulty. The following common species may be mentioned.

Coleosporium Ipomoae (Schw.) Burr. on *Ipomoea,* urediniospores with uniformly thin wall 1-1;5μ; *C. Campanulae* (Pers.) Lev. on *Campanula,* urediniospores with uniformly thick wall, 2-3.5μ; *C. Vernoniae* B. & C. on *Vernonia,* urediniospores with wall 1-2μ at sides, often 2-5μ above; *C. Solidaginis* (Schw.) Thüm. on *Aster, Euthamia,* and *Solidago,* urediniospores with uniform wall, about 1-2μ. The urediniospores of the different species do not vary much in size, averaging 14-22x20-30μ.

FAMILY 2. UREDINACEAE

This family is represented in North America by seventeen or eighteen genera and a considerable number of species. In the United States only seven of these genera are common, the others being chiefly from tropical regions.

Key to the Principal Genera

Teliospores in definite and limited sori, usually on the leaf-blades; urediniospores rounded.

Telia conspicuous, raising or breaking through the epidermis, teliospores 1-celled.

Telia in the form of cushion-like masses; urediniospore-wall verrucose.

Teliospores in a single layer; urediniospores with intermixed paraphyses.....Genus *Melampsora*

Teliospores in chains; uredinia with a delicate peridium or naked.....Genus *Melampsoropsis*

Telia extruding as long filiform columns; urediniospore-wall echinulate.....Genus *Cronartium*

Telia inconspicuous, in a layer in the epidermal cells or just below them, teliospores 2-4-celled.

Teliospore-wall brownish; uredinial peridium opening with a definite orifice surrounded by longer cells, urediniospores echinulate.....Genus *Pucciniastrum*

Teliospore-wall colorless; uredinial peridium without definite orifice, the cells longer at the sides and shorter toward apex, urediniospores verrucose.....Genus *Hyalopsora*

Teliospores solitary, or in very loose groups, usually buried within the parenchymal tissues; urediniospores pointed.....Genus *Uredinopsis*
Teliospores forming continuous layers around elongated and thickened stems, not erumpent; uredinial stage lacking.....Genus *Calyptospora*

GENUS MELAMPSORA CAST.

A prior name for this genus is *Uredo*. But as that word has been in general use as the name of a stage, the one called in this paper the uredinial stage, and its restriction to a true generic application might lead to confusion, a later and more commonly used name is here maintained.

The genus contains both heteroecious and autoecious species. The aecia have no peridium.[2] A conspicuous feature of the uredinia are the numerous, large paraphyses. Both aeciospores and urediniospores have colorless, verrucose walls. There are three common species.

Species

M. Medusae Thüm. Urediniospores smooth on two sides which are thickened, I on *Larix*, II and III on *Populus*.

M. Bigelowii Thüm. Urediniospores with walls evenly thick and evenly verrucose, I also on *Larix*, very similar to the preceding, II and III on *Salix* (see Fig. 3).

M. Lini (Schum.) Desm. Autoecious, on *Linum*.

GENUS MELAMPSOROPSIS (SCHROT.) ARTH. (Sometimes included in CHRYSOMYXA).

Found in its uredinial and telial stages only on the order *Ericales*. The aecia so far as known occur on the leaves or cones of spruces (*Picea*). Several of the species are rather rare. *M. Pyrolea* (DC.) Arth. on wintergreen (*Pyrola*) is common. There are two species on Labrador tea (*Ledum*); *M. ledicola* (Peck) Arth. with the II and III on the upper side of the leaves, urediniospores moderately large, 18-29 x26-36μ, wall 2.5-3μ thick; and *M. abietina* (A. & S.) Arth. with sori on the under surfaces of the leaves, urediniospores moderately small, 14-22 x20-30μ, wall 1.5-2.5μ thick. A uredinial stage on *Cassandra calyculata*, which is very rarely accompanied by telia, is *M. Cassandrae* (P. & C.) Arth.

GENUS CRONARTIUM FRIES.

A very striking genus in the telial stage on account of the long (0.5-3 mm.) filiform spore-columns. Cultures have proven that

2. The term caeoma is often applied to such forms, i. e. to aecia in which the peridium is lacking.

the aecial stages are the blister rusts of the twigs, branches and trunks of pines (*Pinus*).

Species

C. Comptoniae Arth. A common form along the north Atlantic coast on the sweet gale (*Myrica Gale*) and sweet fern (*M. asplenifolia*).

C. Quercuus (Brond.) Schröt. is widely distributed on various species of oak (*Quercus*). The aecial stage (called *Peridermium cerebrum* Peck) on pines forms globoid swellings of the branches upon which the orange-yellow aecia are arranged in a cerebroid fashion.

C. ribicola Fisch. de Waldh. is a rather recent importation from Europe and is a very serious disease of white pine (*Pinus strobus*) seedlings. The telial stage on *Ribes* (currants) is also appearing in this country.

Genus Pucciniastrum Otth.

The characteristic feature of this genus is the hemispherical or subconical peridium of the uredinial stages with a pore-like orifice at apex surrounded by elongated cells, which are often echinulate above. Owing to the fact that the telia remain covered (indehiscent) they are somewhat difficult to study, and the partitions of the teliospores being vertical are not readily made out. Of the nine or ten species the following are the more common ones, others may be found upon *Hydrangea, Rubus, Arctostaphylos,* and *Vaccinium.*

Species

P. Agrimoniae (Schw.) Tranz. Common on *Agrimonia* from New England to North Dakota southward to Florida and Mexico.

P. pustulatum (Pers.) Diet. Widely distributed, especially northward on various species of *Epilobium.*

P. Pyrolae (Pers.) Diet. on *Pyrola* and *Chimaphila,* can be distinguished from the *Melampsoropsis* on *Pyrola* by the nature of the uredinial peridium and the echinulate markings of the urediniospores.

Genera Hyalopsora Magn. and Urediniopsis Magn.

These genera include all of the rusts which are known on ferns in America. The cycle of development in both genera is not well understood. Both have two spore-forms

known on the fern-hosts aside from the telia. Some authors have looked upon one of these forms as aecia and the other as uredinia but evidence is lacking to prove the correctness of this assumption and recent work[3] indicating the heteroecious character of certain species of *Uredinopsis* throws some doubt upon that disposition. For the most part the two genera occur upon different genera of ferns; *Hyalopsora* on *Phegopteris, Cystopteris, Polypodium,* and *Pellaea; Uredinopsis* on *Osmunda, Onoclea, Pteridium, Asplenium,* and *Dryopteris.* The two genera can be further separated by the fact that one of the spore-forms of *Uredinopsis* has fusiform spores which are acute or beaked above, with a wall which is smooth except for two longitudinal ridges bearing single rows of minute projections, while both spore-forms in *Hyalopsora* have rounded spores with evenly verrucose walls. *H. Aspidiotus* (Peck) Magn. is the most widely distributed of the four species belonging to that genus; *U. Osmundae* Magn. on *Osmunda, U. mirabilis* (Peck) Magn. on *Onoclea,* and *U. Atkinsonii* Magn. on *Asplenium* and *Dryopteris* are the best known of the seven described species of *Uredinopsis.*

GENUS CALYTOSPORA Kühn.

Only one species is at present recognized in this genus, *C. columnaris* (A. & S.) Kühn (*C. Goeppertiana* Kühn). Uredinia are lacking; the telia are found on *Vaccinium,* and the aecia on the balsam fir (*Abies balsameum*) in this country. The telia form an even, polished, reddish-brown layer around the elongated and enlarged stems; the teliospores are closely packed in the epidermal cells, the wall of each spore very thin at the sides 0.5-0.8μ, somewhat thicker above 1-1.5μ.

FAMILY 3. AECIDIACEAE
(Called also PUCCINIACEAE)

In this family belong the largest number of rusts, including for the most part those that cause serious injury to economic plants. The number of genera to be dealt with is dependent upon the scheme of classification which one follows. According to the old method any species of the group having free teliospores would belong to the genus *Puccinia* if it possessed a single other character, i. e. two-celled teliospores (see Fig. 2, b). Likewise those forms would belong to *Uromyces,* which possess one-celled teliospores (see Fig. 2, a). Such a scheme, based on only one character, brought together, as a genus, species of the most diverse forms and varied affinities. A classification which takes into consideration the nature of the spore-wall, germ-pores, the origin of the sorus, i. e. whether under the cuticle or under the epidermis, the life-cycle, whether one or more stages are lacking, and other important characters will, of course, segregate the species usually placed under *Puccinia*

3. Fraser, W. P. Science, N.S. 36:595. 1912.

and *Uromyces* and increase the number of genera, but it will have the very great advantage of forming groups which have some affinities. Following such a system we have among the more common forms in the United States about twelve genera to consider in the place of two, but this number might be decreased nearly one-half by not recognizing the purely artificial character of number of cells as a basis for generic separation. The present state of knowledge does not seem sufficient, however, to warrant such a change.

KEY TO THE PRINCIPAL GENERA

Teliospores or pedicels, or both, more or less united; uredinia when present naked but often with intermixed paraphyses.
- Teliospores united into a head, or cushion-like body, on a compound pedicel ..... Genus *Ravenelia*
- Teliospores free but borne in groups of two to eight on a common stalk.
  - Life-cycle with all spore-forms..... Genus *Tranzschelia*
  - Life-cycle with pycnia and telia..... Genus *Polythelis*

Teliospores and pedicels both free; uredinia when present without peridium but sometimes with encircling paraphyses.
- Teliospores becoming imbedded in masses of jelly formed by gelatinization of the pedicels, teliospore-pores varying in number and arrangement; uredinia lacking..... Genus *Gymnosporangium*
- Teliospores in definite sori, not becoming gelatinous.
  - Pycnia subcuticular, other sori subepidermal; teliospore-pores when more than one in a cell lateral; uredinia usually with encircling paraphyses.
    - Teliospore-wall more or less conspicuously laminate.
      - Teliospores 2-celled, the wall finely and sparsely verrucose ..... Genus *Uropyxis*
      - Teliospores 2 to several-celled, more or less coarsely verrucose or even smooth.
        - Life-cycle with all spore-forms..... Genus *Phragmidium*
        - Life-cycle with pycnia, aecia and telia..... Genus *Earlea*
    - Teliospore-wall not noticeably laminate.
      - Teliospore-wall spinous, teliospores 3-celled by oblique septa..... Genus *Nyssopsora*
      - Teliospore-wall nearly or quite smooth, the spores 2- or several-celled by transverse septa.
        - Teliospores 2-celled..... Genus *Gymnoconia*
        - Teliospores 3-13-celled..... Genus *Kuehneola*

Pycnia and other sori subepidermal; teliospore-pores one in a cell and apical; uredinia rarely with encircling paraphyses.
Life-cycle with all spore-forms.
Teliospores 1-celled .....Genus *Nigredo*
Teliospores 2-celled .....Genus *Dicaeoma*
Life-cycle with pycnia, aecia and telia.
Teliospores 1-celled .....Genus *Uromycopsis*
Teliospores 2-celled .....Genus *Allodus*
Life-cycle with pycnia, uredinia and telia.
Teliospores 1-celled .....Genus *Klebahnia*
Teliospores 2-celled .....Genus *Bullaria*
Life-cycle with pycnia and telia, or only telia.
Teliospores 1-celled .....Genus *Telospora*
Teliospores 2-celled .....Genus *Dasyspora*

GENUS RAVENELIA BERK.

This genus is especially characterized by the manner in which the teliospores are fascicled on compound pedicels. The spores form heads which are bordered by hyaline cysts that swell more or less in water. The urediniospores are often paler below. The genus occurs, with the exception of one species, upon leguminous hosts included in the families, Mimosaceae, Caesalpiniaceae, and Fabaceae. The exception is on *Phyllanthus* belonging to the Euphorbiaceae. Thirty-eight species have been described in North America, chiefly from Mexico, Central America, and the West Indies. Several occur along the southern border of the United States but only one comes into the central and northern states, *R. epiphylla* (Schw.) Diet. on *Cracca* (*Tephrosia*).

GENUS TRANZSCHELIA ARTH.

A small genus, only two species at present known. The urediniospores have the wall thicker and less echinulate above. The teliospores are 2-celled and a characteristic feature about them, aside from the manner in which they are borne, is the ease with which the two cells separate. One species, *T. cohaesa* (Long) Arth., known only from Texas, is autoecious on *Anemone decapetala;* the other, *T. punctata* (Pers.) Arth., is widespread and heteroecious, O and I on *Anemone, Hepatica,* and *Thalictrum,* II and III on peaches, cherries, and plums.

GENUS POLYTHELIS ARTH.

A small genus which is confined to hosts of the family Ranunculaceae. The teliospores are very similar to those of *Tranzschelia* but the two genera differ very markedly in the life-cycle. A species having both cells of the teliospores globoid is *P. fusca* (Pers.) Arth. on *Anemone quinquefolia* common east of the Mississippi; another with the lower cell considerably elongate, on *Pulsatilla hirsutissima,* is *P. Pulsatillae* (Rostr.) Arth. common from the Mississippi to

Colorado and Montana; and a third with the lower cell somewhat elongate, on *Thalictrum,* is *P. Thalictri* (Chev.) Arth., distributed throughout the northern United States and Canada.

GENUS GYMNOSPORANGIUM HEDW. F.

Characterized, with a few exceptions, by a dingy-white, membranous peridium, which elongates into a tubular form and tends to rupture along the sides; by large peridial cells usually conspicuously sculptured on the inner and side walls (see Fig. 4, a); by aeciospores with colored walls and evident germ-pores[4]; and by teliospores with hyaline pedicels of considerable length, the outer portions of which swell in moisture and become gelatinized to form a jelly-like matrix in which the spores appear imbedded. As regards hosts the genus is restricted in its aecial stage to the family Malaceae (Pomaceae), with three known exceptions, and in its telial stages to the Juniperaceae without any known exceptions. About thirty species have been reported in the United States, of which the following are most likely to be collected.

Species

G. Juniperi-virginianae Schw. (*G. macropus* Link). The common "orchard rust" forming globoid galls on the Virginia red cedar in the telial stage and attacking crabapples and cultivated apples in the aecial stage. The telia on the galls are cylindrical, the galls die after producing a crop of telia.

G. globosum Farl. Also forming telia on the red cedar but chiefly on the genus *Crataegus* in its aecial stage. The telia are wedge-shaped and the mycelium in the galls is perennial, producing new telia between the scars of the sori of previous seasons.

G. germinale (Schw.) Kern (*G. clavipes* C. & P.). The hemispherical telia in this species do not form galls but long gradual enlargements of the twigs or branches. The aecia attack the fruits and often the twigs of *Cydonia* (quince), *Amelanchier, Aronia,* and *Crataegus.* The peridium is unusually whitish. The telia occur not only on the red cedar (*Juniperus virginiana*) but also on the junipers (*Juniperus communis* and *J. siberica*).

Along the Atlantic coast are two conspicuous species on the branches of

4. In most genera germ-pores are apparently wanting or obscure in the aeciospores but are usually evident in the urediniospores and teliospores.

the white cedar (*Chamaecyparis thyoides*); *G. Ellisii* (Berk.) Farl. with yellowish filiform telia and *G. Botryapites* (Schw.) Kern with brownish pulvinate sori. *G. Betheli Kern* is a gall form very destructive to the red cedar (*J. scopulorum*) in the Rocky Mountains; *G. juvenescens* Kern in the same region causes witches' brooms on the cedars.

Genus Uropyxis Schröt.

A genus usually separable from all others here described by the laminate wall of the teliospores, the outer layer of which is gelatinous, swelling in water. The species are more common southward into Mexico. *U. sanguinea* (Peck) Arth. on *Mahonia* (*Berberis*) is distributed throughout the western mountain region from Washington and Wyoming south to Guatemala. *U. Amorphae* (Curt.) Schröt. on *Amorpha* is widely distributed over the United States and especially abundant in the Mississippi valley. In the former the gelatinous outer layer is relatively inconspicuous, in the latter 1-3μ thick at apex and base of spores and 7-15μ at the sides.

Genus Phragmidium Link.

The cycle of development in this genus includes all sporeforms and all species are autoecious. For hosts it is restricted to a single family, the Rosaceae. The aecia and uredinia are both without peridium but usually with encircling paraphyses (see Fig. 4, b). The teliospores are usually more than two-celled by transverse septa (Fig. 2, d). Sixteen species have been described in North America, four on the tribe Rubeae, eight on the tribe Roseae, and four on the Potentilleae. *P. imitans* Arth. on *Rubus strigosus* is the most widely distributed of the first group. *P. disciflorum* (Tode) James and *P. subcorticinum* (Schrank) Winter are common on cultivated roses in many parts of the United States, especially the northern states east of the Rocky Mountains. The teliospores of the former are 5-9-celled, with walls blackish-brown, opaque, 5-7μ thick, of the latter 5-7-celled, the walls chestnut-brown, not very opaque, 3-5μ thick; in both species the teliospore-walls are verrucose and the pedicels swell in water. *P. Andersoni* Shear on *Dasiphora fruticosa* and *P. Potentillae* (Pers.) Karst. on various species of *Potentilla* are representatives of the third group. In *P. Andersoni* the teliospores are furnished with a hyaline papilla at the apex and the pedicel is much swollen in the lower part, while in the other the apex has no apiculus and the pedicel is not swollen.

GENUS EARLEA ARTH.

This genus resembles *Phragmidium* but the cycle of development includes only pycnia, aecia, and telia. Several species have been referred here but only one of them is common, that on various roses. This species differs from the species of *Phragmidium* common on roses by the teliospores having smooth walls and pedicels not swelling in water and also by the fact that the telia are large and appear always upon the stems, while in that genus they are small and only upon the leaves.

GENUS NYSSOPSORA ARTH.

The teliospores differ from those of all other genera (except *Triphragmium*) in having the teliospores divided into cells by oblique partitions in such a way as to make them triangularly 3-celled (Fig. 2c). They differ from *Triphragmium,* which is not discussed in this paper, by the short life-cycle and the spinous character of the teliospore walls. Only one species, *N. clavellosa* (Berk.) Arth. on *Aralia nudicaulis* is known east of the Rocky Mountains; another in the western mountainous region is *N. echinata* (Lev.) Arth. on *Ligusticum* and *Oenanthe.*

GENUS GYMNOCONIA LAGERH.

Here belongs the orange rust of blackberries and raspberries (*Rubus* spp.) which is so well known. It is the only species of importance and is best known under the name *G. interstitialis* (Schlecht.) Lagerh. The pycnia and aecia are the conspicuous stages; no uredinial stage exists.

GENUS KUEHNEOLA (LINK) ARTH.

Another genus with several species on the Rosaceae but differing from those already described on that family. The teliospores are smooth and few- to many-celled by transverse partitions. The aecial stage is lacking. *K. obtusa* (Strauss) Arth. with 3-5-celled teliospores is a common form on *Potentilla canadensis; K. uredinis* (Link) Arth. with 5-13-celled (usually 5-6) teliospores is another rust of *Rubus,* but is not at all conspicuous and can not be confused with *Gymnoconia.* One species, *K. Gossypii* (Lagerh.) Arth., is a rust of the cotton plant known from southern Florida and the West Indies.

GENUS NIGREDO ROUSS.

To this and the following seven genera belong most of the species formerly referred to the old composite genera *Uromyces* and *Puccinia*. By the use of the generic names here adopted the important information concerning the life-cycle is conveyed in the name without the necessity of the roundabout method of explaining the status with a phrase.

The aecia are usualy cupulate, aeciospores borne in chains with colorless, verrucose walls; the uredinia are without peridium or encircling paraphyses, urediniospores borne singly on pedicels, the walls colored, echinulate or verrucose, the pores variously arranged; the telia are sometimes long covered by the epidermis, teliospores free, stalked, 1-celled (see Fig. 2a), the wall firm, colored, smooth or verrucose, with one apical pore. The genus *Nigredo* is represented by a large number of species, many of which are common in the United States. It will be possible to mention only a few of those most likely to be found.

Species

Host belonging to grass family (Poaceae).

Urediniospore-pores 3 or 4, equatorial, the spores medium-sized (15-19 x18-23μ); on species of *Panicum*, chiefly *P. virgatum;* I unknown. .....*N. graminicola* (Burr.) Arth.

Urediniospore-pores about 8, scattered, the spores large (19-27x25-37μ); on species of *Spartina;* I on *Steironema, Polemonium, Phlox,* and *Collomia*.....*N. Polemonii* (Peck) Arth.

Host belonging to sedge family (Cyperaceae).

Urediniospore-pores 4, equatorial; on *Scirpus;* I on *Cicuta* and *Sium* .....*N. Scirpi* (Cast.) Arth.

Urediniospore-pores 2, above the equator; on Carex; I on *Aster* and *Solidago*.....*N. perigynia* (Hals.) Arth.

Host belonging to family Araceae; urediniospore-wall thicker above, pores 4; on *Caladium;* autoecious.....*N. Caladii* (Schw.) Arth.

Host belonging to family Juncaceae; urediniospore-pores 2, equatorial; on *Juncus;* I on *Ambrosia, Arnica,* and *Cirsium*.....*N. Junci* (Desm.) Arth.

Host belonging to family Polygonaceae; urediniospore-pores 4, equatorial; on *Polygonum;* autoecious.....*N. Polygoni* (Pers.) Arth.

Host belonging to family Carophyllaceae; urediniospore-pores 3 or 4, equatorial; on *Dianthus* (carnation); I on *Euphorbia* (not known in United States).....*N. caryophyllina* (Schrank) Arth.

Host belonging to family Fabaceae.
Urediniospore-pores 3-6, scattered; on *Trifolium pratense* (red clover); I unknown.....*N. fallens* (Desm.) Arth.
Urediniospore-pores 3 or 4, equatorial; on *T. repens* (white clover; autoecious.....*N. Trifolii* (Hedw. f.) Arth.
Urediniospore-pores 2, equatorial; on *Strophostyles, Vigna,* and *Phaseolus* (including the garden bean); autoecious.....*N. appendiculata* (Pers.) Arth.
Host belonging to family Asclepiadaceae; urediniospore-pores 4, equatorial; on *Asclepias;* I unknown.....*N. Howei* (Peck) Arth.

GENUS DICAEOMA S. F. GRAY.

This genus resembles *Nigredo* in every important character, differing only in having teliospores with two cells. It is without doubt the largest of the rust genera. Here belong the bulk of grass and sedge rusts, including the important cereal rusts. Dicotyledonous plants of eighty or ninety genera representing about twenty-five families serve as hosts for species of this genus, but most of these are not of economic interest or of common occurrence.

Species

Host belonging to grass family (Poaceae).
Telia early naked, blackish, chiefly on the culms and sheaths; urediniospore-pores 4, equatorial; on wheat, oats, rye, timothy and several wild grasses (*Agrostis, Agropyron, Elymus*); I on barberry.....*D. poculiforme* (Jacq.) Kuntze (=*Puccinia graminis* Pers.)
Telia long covered by the epidermis, often grayish-black; chiefly on the leaf-blades.
Urediniospore-wall brown; the pores about 6, scattered.
Urediniospores with intermixed paraphyses; telia rarely formed in our region; on species of *Poa,* common on blue-grass; I on *Tussilago,* rare.....*D. epiphyllum* (L.) Kuntze (=*Puccinia poarum* Niels.)
Urediniospores without paraphyses; teliospores germinating in the fall; on rye (*Secale cereale*); I on *Lycopsis,* not yet found in America.....*D. Asperifolii* (Pers.) Kuntze (=*Puccinia rubigo-vera* DC.)
Urediniospore-wall yellow or colorless.
Teliospores with finger-like projections at the apex; on oats and wild grasses (*Cinna, Holcus* and others); I on buckthorn (*Rhamnus*).....*D. Rhamni* (Pers.) Kuntze (=*Puccinia coronata* Cda.)

Teliospores with smooth apex; on wheat; I unknown.....
.....*D. triticina* (Erikss.) Kern.
(=*Puccinia triticina* Erikss.)

Host belonging to sedge family (Cyperaceae).
Urediniospore-pores 3 (in occasional spores 4), equatorial.
Urediniospores large (18-26x24-39μ); teliospores large (39-71μ long); on species of *Carex;* I on *Urtica*.....*D. Urticae* (Schum.) Kuntze
Urediniospores medium-sized (15-21x19-25μ); teliospores medium-sized (37-58μ long; on *Carex;* I on *Ribes*.....
.....*D. Grossulariae* (Schum.) Kern.
(=*Puccinia Grossulariae* (Schum.) Lagerh.
Urediniospore-pores 2, in the upper part of spore.
Urediniospores medium-sized (15-19x19-24μ); teliospores medium-sized (35-50μ long); on *Carex;* I on *Aster, Solidago,* and *Erigeron*.....*D. Erigeronatum* (Schw.) Arth.
Urediniospores large (17-21x23-32μ); teliospores large (42-65μ long); on *Carex;* I on *Sambucus*.....*D. Sambuci* (Schw.) Arth.
Host belonging to composite family, genus *Helianthus;* autoecious.....
.....*D. Helianthi* (Schw.) Kuntze

Genus Uromycopsis (Schröt.) Arth.

The character of the pycnia, aecia, and telia are essentially like the genus *Nigredo,* but the uredinial stage is wanting. The telia often arise within the aecia or about them from the same mycelium. A good example of the genus is *U. Psoraleae* (Peck) Arth. on various species of *Psoralea* from Minnesota, Illinois and Texas westward to the Pacific coast. The genus is more common westward.

Genus Allodus Arth.

This genus bears the same relation to *Dicaeoma* that *Uromycopsis* does to *Nigredo. A. Podophylli* (Schw.) Arth. is a common and widely distributed species, occurring on *Podophyllum peltatum.* The teliospore-walls of this species are especially interesting on account of the straight or curved conspicuous spines with which they are beset.

Genus Klebahnia Arth.

No cupulate aecia are present in this genus, the pycnia being followed by a stage of the uredinial-type. Only a few species have been referred here of which the more common one is *K. Glycyrrhizae* (Rabh.) Arth. on *Glycyrrhiza.* This is found from North Dakota and Kansas westward.

GENUS BULLARIA DC.

Resembling *Klebahnia* except for the possession of teliospores having two cells. A widespread species is on various members of the family Cichoriaceae, *Hieracium, Agroseris, Nothocalais,* and *Crepis,* for which the oldest name seems to be *B. Hieracii* (Schum.) Arth. The teliospore-walls are finely verrucose and uniformly thick, 1-1.5μ. Another species on false boneset (*Kuhnia*) is *B. Kuhniae* (Schw.) Kern (*Puccinia Kuhniae* Schw.) with teliospore-walls smooth and thicker above, 3-4μ at sides, 5-7μ above.

GENERA TELOSPORA ARTH. and DASYSPORA B. & C.

To these genera belong species with short life-cycles. In some the teliospores germinate only after a resting period (micro-forms), in others they germinate at once (lepto-forms). The telia are usually compact and arranged in circinating or crowded groups. Most specimens showing teliospores germinating upon maturity can be placed here with considerable confidence, as they very rarely belong to genera with other spore-forms in the life-cycle. The 1-celled forms belong to *Telospora,* and the 2-celled forms to *Dasyspora.* Only a few species are known in the former genus. *Telospora* Rudbeckiae (A. & H.) Arth. on *Rudbeckia laciniata* is the most likely to be met with. *Dasyspora* is a large genus. *D. Anemones-Virginianae* (Schw.) Arth. on *Anemone* and *D. Xanthii* (Schw.) Arth. on *Xanthium* are of common occurrence.

FORM-GENERA

In addition to the forms of known life-cycle, which may be referred to true genera, there are many forms whose life-cycle is too imperfectly understood to permit them to be placed with confidence in any of the known genera. Many of these can be recognized merely as a stage and judging from analogy it is safe to assume that they cannot be independent but must be associated with other stages. In order that such forms may have names so that they may be discussed more easily the practice has grown up of using certain terms as if they were really generic names, when in fact they represent only stages. For example aecial forms of the usual cluster-cup type whose connections are unknown are placed under *Aecidium;* aecial forms of the blister-type inhabiting the pine family

(Pinaceae) are treated by most writers under *Peridermium;* while aecial forms lacking a peridium are considered under *Caeoma.* Uredinial and other similar looking stages are referred to *Uredo.* These names which are accorded generic treatment, but which include only isolated stages, are referred to as *form-genera,* and as such they serve a useful purpose in disposing of the residue of imperfectly known forms.

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DEPARTMENT OF NOTES, REVIEWS, ETC.

It is the purpose, in this department, to present from time to time brief original notes, both of methods of work and of results, by members of the Society. All members are invited to submit such items. In the absence of these there will be given a few brief abstracts of recent work of more general interest to students and teachers. There will be no attempt to make these abstracts exhaustive. They will illustrate progress without attempting to define it, and will thus give to the teacher current illustrations, and to the isolated student suggestions of suitable fields of investigation.—[Editor.]

NOTES ON SOME PECULIAR SENSE ORGANS FROM DIPTERA

The Diptera are generally conceded to be descended from four-winged ancestors, the posterior pair of wings having become rudimentary. The rudiments of this posterior pair of wings are called halteres, and are found as small club-shaped organs just back of the normal wings.

These organs play an important part in the orientation of the body during flight. If they are removed or otherwise interfered with, the flight is disturbed and in some cases prevented.

At the base of the stalks of the halteres are to be found some highly developed organs, which appear to be sense organs.

In Figs. 1 and 2 which are drawn from an Ortalid, called *Stranzia longipenis,* will be seen a dorsal and a lateral view of a halter. There are apparently two kinds of sense organs depicted here, one (A) and (C) situated on opposite sides of the stalk, and one (B) situated on the chitinous sheath which covers the base of the organ on the dorsal side. (See Plate I).

Fig. 2 shows a side view of the halter. These sense organs when viewed with a higher power present an appearance something like Fig. 3. There are ten rows of the oval disks, with as many rows of rudimentary hairs or spines between them. Organs (A) and (C) are identical in these particulars. These oval disks have a swelled or crowning surface, which leaves them distinctly raised in rows.

In Fig. 4, is a diagram of the disk arrangement of the basal sheath. Here the disks lie in rows between chitin ridges, those nearest the center being nearly overgrown with small spines.

An explanation of the nature and function of these organs is not certain nor easy. The following is offered as suggestive.

Let us look for a moment at the more primitive type of fly; we may find here a clue to the course these structures may have followed in their evolutionary degeneration.

In the Brachycera, we find a type of insect which has very simple forms of wings, the venation being mostly absent except for a few parallel ribs which run lengthwise of the wing. The wings are covered with spines which lie in rows alternating with each other as in Fig. 7. The halteres still retain their wing shape and the spines on them preserve the arrangement found on the anterior wings.

In another family still more highly organized, we find the rows of spines more definitely gathered and specialized into rows, which rows of spines are separated by spaces such as are seen in Fig. 5.

Finally, in the elaborate organization of the soaring and poising flies we find, as described above for Stranzia, the rows of hairs or spines alternating with the rows of disks. Microtome sections of these organs show the oval disks as hollow and filled with fluid during life.

The rows of degenerate spines seem to be connected with the central nervous system, and are assumed to be sensory.

From a histological standpoint the halter is composed of an ectodermal layer of cells, which secretes the chitin with its many sensory spines, and an interior mass composed of trachea, nerves, and fluids with corpuscles. See Fig. 9 for a very diagrammatic view of a section of the halter.

Fig. 8 is a much enlarged view of the cells in the sense organ on the stalk of the halter. The disks are formed from large oval cells (A), and the sensory cells are at (B).

The writer is unable to say whether the disc cells are also sensory; altho it is possible that they are. It seems at least probable to him that they may be considered as homologous with the ordinary smooth membrane interspinal spaces on the normal wing. It is not clear from the structure of these organs just how they contribute to equilibrium, unless in some way they control the blood supply to the vascular terminal bulb.

Some experiments conducted to determine what relation these sense organs on the halteres have to flight and to orientation in flight may prove interesting to those who have not made special study of the subject.

In order to determine the relation of the halteres to flight the writer removed the entire halteres, by cutting, in a number of specimens of Muscidæ. Flies so treated were all incapable of controlling their flight, usually pitching violently downward when attempting to fly.

A similar number of flies was taken, and, without removing the halteres, a small amount of liquid balsam was introduced under the sheath and over the sense organs. Specimens treated in this way could not be induced to undertake flight.

These two experiments show clearly that the halteres play an important role in equilibrium in flight, and that they can be put out of commission, as effective organs, without actual removal. This suggests the existence of certain subordinate parts on which the functioning of the organ depends.

It now remains to localize, if possible, the responsible portion of the halter. In doing this, larger flies, as Sarcophagidæ, Syrphidæ, and Tachinidæ, were used. An effort was made in these flies to injure the structures referred to above as sense organs, and to confine the injury to these. Cauterization with a hot needle was attempted; but this was difficult to control, and often resulted in too extensive a wound. The other method used was the application to the so-called sense organs of a small amount of nitric or sulphuric acid, without allowing it to reach the terminal bulb. The flies were held for a minute or so to allow the acid to act. Insects treated in this way pitch headlong in attempted flight much as those whose halteres were removed. Some forty specimens were so treated. One of two conclusions seems necessary:—either the acid penetrates and essentially destroys the whole organ, or there is a special sensory portion which was destroyed and prevented the ordinary reaction.

The conclusions which the writer thinks reasonable are:

1. The halteres are necessary to successful balancing in flight in Diptera.

2. The peculiar and definite organs at the base are sense organs, and are necessary in giving the halteres functional value.

3. These sense organs are in some way aroused by the changes in position, and thru them the central nervous system is enabled to control the process of balancing.

A CONVENIENT DROPPER FOR USE IN CUTTING CELLOIDIN SECTIONS

A very useful aid in cutting celloidin sections is shown in the accompanying figure (Plate II). This piece of apparatus was in stock when the writer assumed charge of this laboratory, and he is not acquainted with its history. While it is not listed in any of the dealers' catalogs that the writer has examined, it may be made at a very slight cost in any machine shop.

It consists of a glass oil-cup (1) of about 40 cc. capacity, with a mill-head (2) at the top to regulate the flow of alcohol. The cup is fastened to a bar (3), which is slotted for about ¾ its length to receive the bolt that extends through the column (4) that holds the cup a few inches above the knife (5). The head of the bolt mentioned above is of the proper shape to fit into the slot in the knife-carrier, and the thumb-nut (6) on the other end of the bolt tightens at one time both the bar (3) to the column (4) and the column to the knife carrier. This thumb-nut and its bolt, which, except in length, are exactly those (7) that hold the knife in position, make it possible instantly to adjust the cup so that the alcohol will fall on any desired part of the knife; and since the apparatus is attached to the carrier it will always be over the same part of the knife even in microtomes where it is the knife that moves. If all the metal parts are nickel-plated it will obviate trouble in drying off the alcohol to prevent rusting.

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CRITICAL ILLUMINATION FOR THE MICROSCOPE

In a brief paper (J. Queck. Micr. Club. Nov. 1912) Reid gives some important suggestions for critical illumination, which will certainly be of value to beginners in the use of the microscope and to many older users who have not given critical attention to the sub-

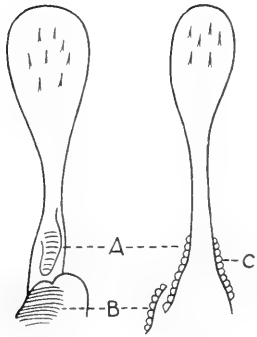

Fig. 1 Fig. 2

Fig. 3

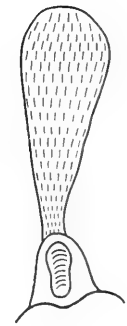

Fig. 6

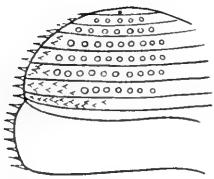

Fig. 4

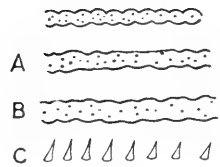

Fig. 5

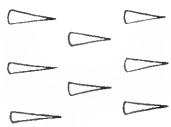

Fig. 7

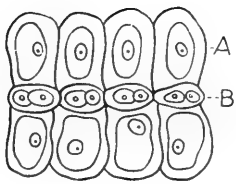

Fig. 8

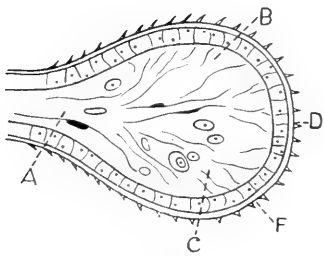

Fig. 9

PLATE I
Sense Organs of Diptera

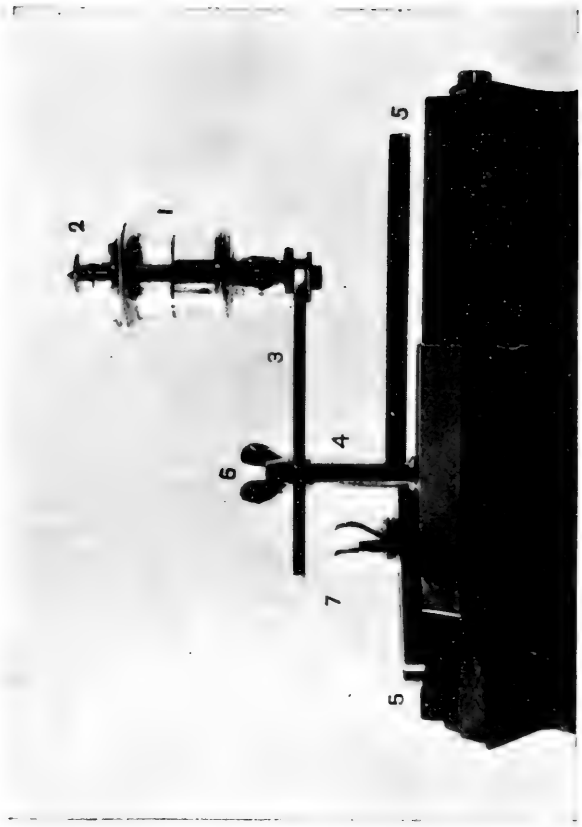

PLATE II
Dropper for Celloidin Sectioning

ject. There is little question that most of us, reared in school laboratories, do not get the nice, exact results in the use of microscopes which are obtained by the thorogoing students of microscopy.

Certain simple precautions leading to good illumination introduce the paper:—Cut out all unnecessary light from the room, so that no light gets to the eye except thru the microscope; save the best eye for critical moments by using the other eye for preliminary steps; use color screens complementary to the stains used, green for red, yellow for blue, etc. The subject of illumination itself the author discusses under these heads: The most suitable light; collecting lenses; principles of correct illumination both of the field and of the object itself; condensers; distance of lamp from substage mirror; critical and non-critical illumination; working aperture; general arrangement of light and apparatus in high, medium, and low-power work.

For the detailed discussion of these topics the readers must be referred to the original paper.

CLEANING DIATOMS

Blake (Am. Jour. Sci. Jan. 1913) calls attention to the interest in cleaning, mounting, and study of diatoms. After recounting the difficulties attendant on the usual methods he describes a method originated by himself some twenty years ago.

Instead of the older method of treating with acid, diluting with water, and repeated decanting, the author devises an organic seive made by cementing a thin cross-section of some coniferous wood to a small glass vial whose bottom has been cut off for the purpose. The wood is cut about one-quarter millimeter in thickness, from a suitable piece of wood kept until the operation in boiling water. This is done by means of a sharp, thin-edged chisel.

The operation of cleaning the diatoms consists of placing the digested diatom material, moderately diluted, in the vial, and by means of a suitable rubber compression bulb, alternately pressed and released, of forcing the acids and salts thru the seive, and the clay and fine sand thru or into its pores. These diatoms which are longer than the diameter of the pores will remain behind with larger grains of sand which must be removed in some other way.

It is necessary to see that the strainer does not become choked. This may be prevented by shaking. The strainer should, of course, be kept in water between uses. When it finally becomes clogged with sand, a new one must be put on.

By using wood with different sized conducting vessels, a sorting of the diatoms may be affected. By using pine, spruce, white wood of the red cedar, a graded series of strainers can be had, the last being much finer than the first.

STAINING PROTOZOA

Darling (Science: Jan. 10, 1913) calls attention to the dearth of knowledge of the acidophilic substances in the nuclei of protozoa, owing to the predominant use of basophilic staining substances, and to the "lack of a satisfactory technic for demonstrating acidophilic substance in wet fixed films."

The author suggests careful differentiation of such polychrome stains as Romanowsky or Hastings-Giemsa, by ammoniated ethyl alcohol. Under such conditions, studying *Entamœbæ,* he found a definite arrangement of an acidophilic substance (oxychromatin) within the nucleus, showing a structure quite different from that shown with the usual basichromatin stains. He believes that careful and critical study will reveal that this oxychromatin may have important functional relations to the changes that are so well known in the true chromatin in nuclear activity.

DOUBLE-STAIN METHOD FOR THE POLAR BODIES OF DIPHTHERIA BACILLI

Dr. Marie Raskin (Apoth. Ztg. XXVII, p. 10; Abstr. United St. Naval Med. Bull. Vol. 6, No. 4, p. 611) proposes a technic for these bodies, whose distinctive value lies in the fact that only two operations are necessary, i. e., the application of a stain with both colors present, then water washing.

Formula for stain:—

Glacial Acetic Acid.....	5 cc.
Dist. Water	95 "
Alc. (95%)	100 "
Old Sat. sol Methylene blue.....	4 "
Ziehl's phenol fuchsine Sol.....	4 "

Drop mixture in a thin layer over the specimens on the cover glass; heat through the flame. The alcohol ignites and is permitted to burn off, after which the specimen is washed in water and dried. The entire process takes 20-25 seconds, and the stain remains serviceable for any length of time. Polar bodies appear deep blue and the bacilli bright red. Even in smears with a preponderance of other bacteria, individual diphtheria bacilli may be readily and unmistakably identified.

A NEW TECHNIC IN STAINING DIPHTHERIA SPECIMENS WITH TOLUIDIN BLUE

Dr. Constant Ponder (Lancet, July 6, 1912; Abstr. U. S. Naval Med. Bull. Oct. 1912, p. 612) recommends the following treatment for diphtheria bacilli:—

The stain:

Toluidin blue (Grübler)	0.02 gram.
Glacial acetic acid	1 cc.
Abs. Alc.	2 "
Distilled Water to make	100 "

The film made on cover glass is fixed as usual. Spread stain on film. The cover glass is then turned over and mounted as a hang-drop preparation. Typical diphtheria bacilli are said to stain blue, with red granules. The author gives this as a new method, and says it is preferable to either Methylene blue or Neisser's stain.

NOTES FROM MEETING OF THE ILLINOIS MICROSCOPICAL SOCIETY, *Chicago, Oct. 10, 1912*

Mr. N. S. Amstutz showed a useful contrivance for keeping pond life in place. It consisted of a piece of brass about 7/8 in. square and 5/32 in. thick. A series of seven holes were drilled thru it so as to imprison that many varieties of pond life at one time. The plate was placed in a flat bottomed watch glass and each specimen transferred with a pipette to its proper "cell." These could be then studied at will very nicely with a 2/3 objective and various combinations of oculars. The specimens were confined laterally so they were unable to move out of the field of view though having abundant room for vertical movement. With the coarse ad-

justment the up and down variation could easily be followed. It proved a great satisfaction to examine water fleas, mosquito larvae, etc., when fenced in. The holes were arranged 6 in a circle of 1/2 in. diameter and the seventh in the center. Their diameter was determined by measuring the diameter of the field with a stage micrometer and then selecting the next smaller size of twist drill by which to do the drilling. To guard against the smallest animalculæ creeping between the brass and the watch glass the bottom face could be covered with a thin film of balsam, air dried until quite of proper consistency, and then a cover glass pressed into intimate contact, so that no balsam would run into the spaces.

VIDA A. LATHAM, Secy.

BOG SOLUTIONS AND PLANTS

Dachnowski (Bot. Gaz. Dec. 1912) writes on the physiological effects of peat or bog solutions on the plants subjected to them. It has been clearly established that the nature of these organic solutions and of the bacterial flora maintaining life therein is a very important factor in limiting the higher life of these regions. The fact that some plants tolerate these conditions and others do not makes clear a difference in the plants themselves. The writer is endeavoring to see what it is that makes this difference in plants exposed to the solutions. The responsibility must rest either upon difference in diosmotic qualities of the plasmic membranes, or upon differences in cytoplasmic resistence, or on both. He finds the following facts which help to localize the solution of the problem: (1) Some plants may cause the precipitation of the hurtful materials in the solutions in an insoluble form, by enzymic action. This conceivably may take place outside the membrane, inside the cell; or in the membrane itself, affecting its permeability; (2) other plants may possess the power of assimilating with impunity these organic substances.

It is well known that these solutions have little effect on certain xerophytic plants, while they totally inhibit agricultural plants. The value of the work is evident as bearing on the agricultural use of peat lands, on the nature of xeromorphy itself, as well as on the successions of vegetation in the bogs.

EFFECT OF CROPPING ON SOIL BACTERIA

Brown (Centralbl. Bakt. Abt. 2, XXXV, 1912, p. 248) has studied the effect of different kinds of cropping on the bacterial content of the soil. He finds that the number of microorganisms in the soil is much increased by rotation of crops as compared with continuous cropping. The same is true of the nitrifying and nitrogen-fixing powers of the soil. He compares various systems of alternation of crops in this regard. He also discusses the effect of turning under clover, as green manure. He claims that the two year rotation with green manuring is not so effective in increasing the bacteria and bacterial products as the longer term rotations. It is shown that the productivity of the soil is closely related to the bacterial activities within it.

ALTERNATION OF GENERATION IN THE PHÆOPHYCEÆ

In a beautifully illustrated article (Bot. Gaz. Dec. 1912) Yamanouchi gives, from the study of the nuclear and experimental conditions, the grounds for believing that *Cutleria multifida* is the gametophytic phase of a species of which *Aglaozonia reptans* is the sporophytic stage. The nuclei of both male and female Cutleria plants contain 24 chromosomes, which is true also of the gametes themselves. The sporelings resulting from the union of these gametes contain 48 chromosomes and develop into an Aglaozonia form similar to *A. reptans* in nature. On the other hand the nuclei of *Aglaozonia reptans* contain 48 chromosomes, which is reduced in zoospore formation to 24. These zoospores germinate without conjugation, and produce plants similar to young Cutleria in nature, and with 24 chromosomes.

EXPERIMENTS ON THE GERMINATION OF TELEUTOSPORES

Dietel (Centralbl. Bakt. II. 31:95. 1911) reports on the effects of age and temperature and drying, etc., on the germination of teleutospores of *Melampsora*. In the early spring these spores germinate in about 3 days if brought into favorable conditions of temperature and moisture. As the spores grow older the time necessary to germinate decreases. This might be due either to internal ripening or to the progressive changes in the spring tempera-

ture. Temporary drying hastened germination; strong light delayed it; temporary freezing had no effect. Germination takes place at 6°-10° C., but is hastened by higher temperature of 15°-20°.

DIRECTION OF LOCOMOTION IN STARFISH

Cole (Jour. Exp. Zool. Jan. 1913) finds that *Asterias forbesi* in the absence of directive stimuli, in crawling advances most frequently with that part of the body forward in which the madreporite occurs. He found a tendency in these animals to persist in moving with the same parts foremost in a series of succeeding trials; tho there is also a tendency to shift or "rotate" this anterior point successively to other parts. The author thinks the madreporic body may be what determines anteriorness, and shows that the "physiological anterior" of the starfish corresponds in this respect to the anterior parts of the more bilateral spatangoids.

A ROTIFER PARASITIC IN EGG OF WATER SNAILS

Stevens (Jour. Queck. Micr. Club., Nov. 1912) describes a rotifer of the genus Proales which is able to bite a small opening in the tough egg membrane of the snail *Limnaea auricularia,* and by squeezing thru this enters the more fluid portion within. The rotifer feeds on the fluid gelatin of the egg with an occasional attack on the snail embryo itself. As the result of these attacks the snail embryo is finally killed.

In the meantime the rotifer lays its eggs, and later leaves this to enter still other eggs. The larvae hatch and undergo their development, devouring the dead snail embryo and other available substance of the egg. They too later escape and enter other eggs.

This looks somewhat like a parasite in the making. The author says the rotifers do not seem "at home" in the water while making their way from egg to egg.

EUGLENIDS AND THEIR AFFINITIES

Alexieff (Arch. Zool. Exp. Notes et Rev., No. 4. 1912) in connection with the discussion of certain euglenoid forms that are partly or largely parasitic on other animals, makes some interesting suggestions as to the relationships of Protozoa. He thinks the Euglenids

are near the flagellate source of the Sporozoa, and from thence as a main stem arise the Trypanosomes, Coccidians, Gregarines, Haemogregarines. He feels also that the Euglenids may give rise to lines leading to Cystoflagellates and Ciliates.

AN AMEBA WITH TENTACLES

Collin (Arch. Zool. Exp. N. & R., No. 4. 1912) describes a new protozoan combining the characters of Ameba and the Suctoria. The organism has a gelatinous covering whose form is easily changed, and possesses tentacles by which it attaches itself to objects. It has the nuclear and pseudopodial structure of the Ameba. It is a marine form occuring in a culture of seaweed along with other amebæ and Foraminifera.

SOME AMERICAN RHIZOPODS AND HELIOZOA

Wailes (Jour. Linn. Soc. Dec. 17, 1913) reports 161 species and varieties of Rhizopods and 4 species of Heliozoa from collections made in 1911 at Augusta, Georgia, in New Jersey, and at various points in New York. Comment is made upon the small amount of work done on the American species of these groups since the time of Leidy.

Of these, 5 species and 10 varieties are new. Forty of them are recorded for the first time from the United States. About 80% of the species are similar to those found in Europe. The remainder are made of species rarely or not at all found in Europe. The author states that considerable local variation exists in some of the species.

SIZE OF CHROMOSOMES AND PHYLOGENY

Meek (Jour. Linn. Soc. Sept. 24, 1912), thru a study of the diameters of chromosomes, has reached the conclusion that there are three diameters of chromosomes found in animals,—.21μ in Protozoa, .42μ in low Metazoa, and .83μ in high Metazoa. He holds that these measurements are remarkably constant. This arithmetic progression is believed by him to mean a lateral fusion of these chromatic elements in phylogeny.

In respect to length, the author finds, by study of spermatogen-

esis in several species of *Stenobothrus* that the chromosomes of the spermatocytes are made up of rods, sometimes 2 and sometimes 4. The length of these rods varies in arithmetic progression. In each of 4 species studied there are 5 short chromosomes, no two of which are the same length; altho the 5 short chromosomes in one species correspond with the 5 short ones of the others. There are also 3 larger chromosomes in each species, but these long chromosomes do not belong in the different species to the same numerical series. The author believes that the external specific differences between the species are dependent on the differences in the long chromosomes, altho he is unable to establish the correlation between the rod-lengths and the body characteristics.

SPERMATOGENESIS IN HYBRID PIGEONS

Smith (Quart. J. Mic. Sci. 1912, p. 159) reports studies of the sperm formation and structure in the hybrids formed by mating a male pigeon and female domestic dove, and compares these with the condition in pure breeds.

In the first maturation division in the hybrids the chromosomes do not unite to form 8 bivalent chromosomes but occur quite irregularly about the spindle and are finally distributed to the poles irregularly.

The second maturation division is practically suppressed. The secondary spermatocytes proceed at once to form spermatids and spermatozoa. Many of these are on the average twice the normal size, altho otherwise apparently normal structurally. In other cases there were structural abnormalities.

It is known experimentally that hybrids of these stocks are infertile, and it seems that the sterility may be due to the inability of the specifically different chromosomes to unite in the normal synapse, with the consequent disturbance in the whole maturation process.

MALE GERM CELLS IN NOTONECTA

Browne (Jour. Exp. Zool. Jan. 1913) discusses the differences in form and number of the chromosomes in three species of Notonecta. She finds that the differences in the chromosome condition may be explained in these species by the relations of two particular

chromosomes. In *N. undulata* the two chromosomes in question are always separate; in *N. irrorata* are always united to form a single body; and in *N. insulata* they may be separated in the first spermatocyte division, but are united in the second.

The author traces the origin of the chromosomes from the karyosphere in the three species, and their behavior in the growth stages and maturation divisions.

INTERSTITIAL CELLS OF TESTIS AND SECONDARY SEX CHARACTERS

J. des Cilleuls (C. R. Soc. Biol. Paris, 1912, p. 371) finds a strict coincidence in the development of the interstitial cells of the testis and the secondary sexual characteristics of the cock. In chickens the external marks of sex do not begin to appear until about the thirtieth day. By the time the chicks are 45 days old the pullets show a greater development of the tail feathers and the cockerel more color and size of comb. The sex distinctions increase from this point. The author claims that the secondary sex characters in the male bird begin to show with the oncoming of the interstitial cells, and increase as these increase. The author believes that the secretion of the interstitial cells acts as a hormone in stimulating the growth of the characteristic male secondary structures.

MICROBIOLOGY IN RELATION TO DOMESTIC ANIMALS

This book, entitled "Principles of Microbiology," with a subtitle "A Treatise on Bacteria, Fungi, and Protozoa Pathogenic for Domesticated Animals," is written primarily for veterinary students beginning the study of microbiology. It consists, in about equal parts, of matter belonging to general bacteriology and to special applications of this to veterinary science. In the very nature of the case this makes the treatment of general bacteriology somewhat less satisfactory than may be had from text-books on this subject, and limits the author somewhat in his treatment of the part of the subject which is peculiar to the book.

The first twelve chapters are given to such subjects as the biology, morphology, classification of bacteria; the apparatus, methods of sterilization, cultivation, staining, and examination of bacteria; the relation of bacteria to disease. In the part relating to

the work of the veterinarian there are, first, two introductory chapters dealing with the Use of Animals in Bacteriological Examinations and Investigations, and the Bacteriology of Water and Milk. These are followed by eight chapters dealing with the various principal genera and species of microörganisms that produce diseases in domestic animals, together with their pathogenesis and, where known, the treatment. These chapters present very valuable material for the general student of biology, as well as for the veterinarian.

In the concluding chapters the author discusses some of the broader questions of physiology, theory, diagnosis and therapy of the bacterial diseases under the heads:—Specific Bacterial Products, Tissue Reactions and Immunity; Serum Diagnosis; Immunity and Vaccine Therapy. This resumè is very readable and valuable to the general student. The mechanical excellence of the book is all that could be desired.

Principles of Microbiology, by V. A. Moore. Pages 506; illustrated. Carpenter & Co., Ithaca, N. Y. Price $3.50.

BEGINNERS GUIDE TO THE MICROSCOPE

This is an elementary handbook designed to aid the untechnical person to use the microscope for his own pleasure and that of his friends. The need of such a book seems to the author to lie in the great complexity of the modern instrument and the wealth of its accessories, and in the elaborate character of the modern books about the microscope. In a very simple, gossipy way quite suitable to his expressed purpose, the author describes the microscope and its essential parts, the formation of images, illumination; discusses the principles that should guide in the choice of an instrument; gives rules for the use of the instrument and for its care; tells of interesting objects for temporary mounts. There are also sections on the home aquarium, on collecting objects, on mounting for permanent display, and on storing slides.

In many ways it is much to be regretted that there are not more of our modern Americans who turn to such methods of interest and diversion as are suggested here. The use of the microscope as a serious instrument of education and research in schools has in-

creased greatly in this country; but it is remarkable that so few people use it as a means of recreation, pleasure, and general culture.

The Beginners Guide to the Microscope, by Chas. E. Heath, F. R. M. S. Illustrated; 120 pages. Price 1 shilling. Percival Marshall & Co., London.

MICROSCOPY AND DRUG EXAMINATION

In this little book the author seeks to present in a simple and condensed form the elements of microscopy and histology demanded by pharmaceutical students. In Part I, which is given to Microscopy, are discussed briefly,—often too briefly to be satisfactory,—microscopes, microscopic photography, manipulation and care of the microscope, reproduction and measurements of microscopic objects; histology, microchemistry; the preparation and mounting of microscopic objects; cells; plant and animal tissues; microscopy of starches, etc. A series of laboratory exercises illustrating certain part of plant and animal biology follow.

Part II is taken up with suggestions as to the microscopical examination of some 35 "drugs" in their commercial form. In Appendix A is a valuable table defining the various elements constituting and produced by cells, giving their properties and the method of identifying them by staining or otherwise.

The last 50 pages of the book are given to figures illustrating lenses, microscopes, drawing apparatus, tissues, organs, drugs.

Mechanically the book is marred by the unnecessarily large type in which the words desired to be emphasized are printed.

Microscopy and the Microscopical Examination of Drugs, by Charles E. Gabel, Ph.D., Microscopical Food and Drug Analyst Iowa State Dairy and Food Commission. Illustrated; 114 pages. Price $1.00, postpaid. Des Moines, Iowa.

NECROLOGY

Announcement of the death of the following members of the American Microscopical Society has been received since the issue of the last number:

A. E. Aubert, '12, New York City.

Geo. C. Crandall, M.D., '04, St. Louis, Mo.

J. D. Hyatt, Past President and Honorary Member, New Rochelle, N. Y.

PROCEEDINGS

of the American Microscopical Society

MINUTES OF THE CLEVELAND MEETING

The Society was called to order by President F. D. Heald in the Biological Laboratory of the Western Reserve University, Cleveland, Ohio, at 3:30 p. m., Jan. 1, 1913.

The reports for 1912 of the Custodian and Treasurer were read and ordered referred to an auditing committee. This committee was later named by the President, consisting of Professor Frank Smith and Mr. J. E. Ackert, both of Urbana, Illinois.

Due to the fact that only one business session was provided for, it was unanimously agreed to suspend By-laws V and VI, and to nominate officers from the floor. The following officers were nominated and elected for 1913:

President: Professor F. Creighton Wellman, School of Tropical Medicine, Hygiene and Preventive Medicine; Tulane University, New Orleans, La.

First Vice President: Professor F. C. Waite, Medical Dept., Western Reserve University, Cleveland, Ohio.

Second Vice President: Professor H. E. Jordan, University of Virginia, University, Va.

Treasurer (3 years): Professor T. L. Hankinson, Eastern Illinois Normal School, Charleston, Ill.

Elective Members Executive Committee: Dr. H. L. Shantz, Bureau Plant Industry, Washington, D. C.; Professor J. W. Scott, Kansas Agricultural College, Manhattan, Kansas; Professor George E. Coghill, Denison University, Granville, Ohio.

Members of the Council of the A. A. A. S.: Professor F. D. Barker, University of Nebraska, Lincoln, Nebraska; Professor A. M. Reese, University of West Virginia, Morgantown, W. Va.

An informal discussion, without vote, was had concerning the utilization of the Spencer-Tolles Fund for research, and other items of general policy.

The verification and publication of the Minutes were left in the hands of the President and Secretary.

CUSTODIAN'S REPORT FOR YEAR 1912

SPENCER-TOLLES FUND

Reported at Washington Meeting		$3,352.16
Dividends received during year 1912		203.28
Contribution		4.00
		$3,559.44
Less dues paid for Life-members		8.00
Total invested		$3,551.44
Net increase during year		$ 199.28
Grand Totals:		
All contributions to date	$ 700.27	
All sales of proceedings	625.73	
All life-memberships	250.00	
All interest and dividends	2,115.44	$3,691.44
Less:		
All grants	$ 100.00	
All life-membership dues	40.00	$ 140.00
Net balance		$3,551.44

Life-members and Contributors of $50 and over: John Aspinwall, Robert Brown, (deceased), J. Stanford Brown, Henry B. Duncanson, A. H. Elliott, John Hately, Iron City Microscopical Society, and Troy Scientific Association.

MAGNUS PFLAUM, Custodian.

We the undersigned committee hereby certify that we have carefully examined the foregoing account, compared it with vouchers and found the same correct.

FRANK SMITH,
J. E. ACKERT,
Auditing Committee.

ANNUAL REPORT OF TREASURER OF AMERICAN MICROSCOPICAL SOCIETY

December 21st, 1911 to December 26th, 1912.

RECEIPTS

To balance on hand from 1911	$ 67.49
To dues of old members	340.66
To dues of new members	110.00
To initiation fees	165.00
To subscriptions for volume 31	17.00
To subscriptions for volume 32	2.00
To subscribers for volumes other than 31 and 32	94.00
To sales of misc. numbers of Transactions to those not subscribers	38.00
To sale of set of Transactions	70.00
To advertisers in volume 29 and 30	70.00
To advertisers in volume 31	87.40
To E. W. Roberts for donation	125.00
To rebate from Post Office	48.31
Total	$1,234.86

EXPENDITURES

By printing of Transactions, volume 31, numbers 1, 2, and 3	$ 550.53
By engraving plates for Transactions, volume 31	143.47
By purchasing back numbers of Transactions to complete sets	8.00
By postage and express of Secretary	68.93
By same of the Treasurer	15.61
By office expenses of Secretary, stationery, stenography, etc	71.99
By same of Treasurer	17.44
By traveling expenses of Secretary and Treasurer, necessitated by committee meetings at Bloomington and Urbana, Ill	12.20
By Secretary's expenses at the Washington meeting in 1911	25.00
By advertising	50.66
By sundry expenses	3.45
By balance on hand	267.58
Total	$1,234.86

Signed, T. L. HANKINSON, Treasurer.

Examined and found to correspond with books and vouchers.

FRANK SMITH,
J. E. ACKERT,
Auditing Committee.

TRANSACTIONS

OF THE

American Microscopical Society

ORGANIZED 1878 INCORPORATED 1891

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Past Presidents still retaining membership in the Society

R. H. Ward, M.D., F.R.M.S., of Troy, N. Y.,
at Indianapolis, Ind., 1878, and at Buffalo, N. Y., 1879
Albert McCalla, Ph.D., of Chicago, Ill.
at Chicago, Ill., 1883
T. J. Burrill, Ph.D., of Urbana, Ill.,
at Chautauqua, N. Y., 1886, and at Buffalo, N. Y., 1904.
Geo. E. Fell, M.D., F.R.M.S., of Buffalo, N. Y.,
at Detroit, Mich., 1890.
Simon Henry Gage, B.S., of Ithaca, N. Y.,
at Ithaca, N. Y., 1895 and 1906
A. Clifford Mercer, M.D., F.R.M.S., of Syracuse, N. Y.,
at Pittsburg, Pa., 1896.
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at Denver, Colo., 1901.
Charles E. Bessey, LL.D., of Lincoln, Neb.,
at Pittsburg, Pa., 1902.
E. A. Birge, LL.D., of Madison, Wis.,
at Winona Lake, Ind., 1903.
Henry B. Ward, A.M., Ph.D., of Urbana, Ill.,
at Sandusky, Ohio, 1905.
Herbert Osborn, M.S., of Columbus, Ohio,
at Minneapolis, Minn., 1910.
A. E. Hertzler, M.D., of Kansas City, Mo.,
at Washington, D. C., 1911.
F. D. Heald, Ph.D., of Philadelphia, Pa.,
at Cleveland, Ohio, 1912.

The Society does not hold itself responsible for the opinions expressed by members in its published *Transactions* unless endorsed by special vote.

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TRANSACTIONS
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Vol. XXXII APRIL, 1913 No. 2

NOTES ON JAPANESE PROTOZOA

WITH FIGURES AND DESCRIPTIONS OF NEW AND RARE SPECIES

C. H. EDMONDSON AND R. H. KINGMAN

The fresh-waters of Japan afford a wonderful opportunity for the enthusiastic microscopist. Conditions under which simple organisms thrive are not wanting anywhere in that country. Flooded rice fields of the lowlands, cool mountain streams and innumerable lakes, large and small, are teeming with low plant and animal forms.

To what extent systematic study of the microscopic fauna and flora of the waters of Japan has progressed, under the direction of the eminent biologists of that country, the writers of this article are not able to state.

With a view of determining the species of Protozoa characteristic of Japan and comparing them with the American forms, microscopic studies were carried on by C. H. Edmondson during July and August, 1912, in various parts of the main island. Beginning with Kobe, observations were made through the central and eastern sections of the country and as far north as Lake Chuzenji.

Material was gathered from rice fields, small pools, streams and lakes. Collections were made from the following large lakes: Lake Biwi, altitude above sea level 328 ft.; Lake Hakone, altitude 2,378 ft.; Lake Chuzenji, altitude 4,375 ft. Since the survey covered a wide territory with considerable variation in local conditions as well as in altitude, the list of species embodied in this brief report may well represent the characteristic unicellular fauna of the entire country. The portion of this article concerned with Rhizopoda is largely a result of the work of R. H. Kingman, a student of zoology,

who identified and studied many forms from preserved material. By comparing the list which follows with numerous local records of observers in America and other parts of the world one sees some added evidence of the wide distribution of many species of Protozoa.

The accompanying figures, prepared by Mr. Kingman from permanent mounts, represent new, or rare species of Rhibopods or forms showing considerable variation.

Phylum **PROTOZOA**: Subphylum **SARCODINA**: Class RHIZOPODA Subclass AMOEBEA

Order GYMNOMOEBIDA

Family Amoebidae

Amoeba Ehrenberg. *A. proteus* Leidy; *A. guttula* Duj.; *A. sphaeronucleus* Greef; *A. striata* Penard; *A. radiosa* Ehr.; *A. saphrina* Penard.

The species of this genus were not common in any locality. Material from Myoho-in Temple grounds, Kyoto, furnished the best examples. Large individuals of *A. radiosa* were taken from Lake Hakone.

Hyalodiscus Hertwig and Lesser. *H. rubicundus* H. and L.

But one individual was observed. A very typical form, reddish-brown in color. From a rice field, Kyoto.

Arcella Ehrenberg. *A. vulgaris* Ehr.; *A. discoides* Ehr.; *A. costata* Ehr.; *A. arenaria* Greef.

Of the above species *A. vulgaris* is the more widely distributed in Japan. Lake Chuzenji and the region of Kyoto furnished the best material.

Centropyxis Stein. *C. aculeata* Stein.

Found in all localities. Very abundant in Lake Hakone. Great variation in size occurs in this species and some very large forms were observed.

Pixidicula Ehrenberg. *P. cymbalum* Penard.

A species rarely observed. Found in material from Lake Hakone.

Lecquereusia Schlumberger. *L. spiralis* Ehr.; *L. modesta* Rhumbler.

These two speices are widely distributed in Japan, the former being much more abundant. In the typical *L. spiralis* the aperture

is usualy directed obliquely toward one side with a prominent hump at the outer base of the neck. In the common form in Japan the aperture is directed almost straight forward, in very rare cases there being a slight prominence at the base of the neck. Common in Lake Hakone. Typical examples of *L. modesta* were found in lakes on Mt. Rokkozan.

L. epistomium Penard, a common species of the high lakes of Colorado, was not observed in Japan.

Difflugia Leclerc. *D. pyriformis* Perty; *D. lobostoma* Leidy; *D. constricta* Leidy; *D. acuminata* Ehr.; *D. tuberculata* Wallich; *D. lebes* Penard; *D. bacillariarum* Perty; *D. elegans* Penard.

Of the species of *Difflugia* in Japan, *D. elegans* is apparently the most common. It is widely distributed and shows a great range of variation. *D. lebes,* not uncommon in some of the lakes of Colorado, was observed but once, in material from the bottom of Lake Hakone.

Pontigulasia Rhumbler. *P. spectabilis* Penard.

But one individual observed. From Lake Hakone. A very typical form.

Quadrulella Cockerell. *Q. symmetrica* Schultze; *Q. symmetrica* var. *curvata* Wailes.

Very typical forms of the species were taken from shallow lakes on Mt. Rokkozan. The variety, observed but once, was found in Lake Hakone.

Nebela Leidy. *N. collaris* Leidy; *N. crenulata* Penard; *N. hippocrepis* Leidy; *N. triangulata* Lang.

In the material collected in Japan species of *Nebela* were very rare.

There can be no reason to believe, however, that the genus is not well represented in that country. One individual of the rare species, *N. hippocrepis,* was found in material from Mt. Rokkozan. In the ooze from the rocks along the shore of Lake Hakone and from the border of a shallow lake on Mt. Rokkozan was found a species which is here listed under the name *N. triangulata* Lang.

The Japan species resembles, in some particulars, *Nebela bipes* Carter, as described in Clare Island Survey, Part 65, by Wailes

and Penard, and may represent an intermediate form between *N. triangulata* and *N. bipes.*

In the Japan form the shell is very transparent, compressed, irregular in outline with the fundus region inflated in an asymmetrical manner. The aperture is slightly oval.

Great variation exists in the form of the shell and in the arrangement of the plates. In some the plates are circular or oval, distinctly separated from each other with the ground substance of the shell intervening. In others the plates are closely crowded together and very irregular in outline, while in some the plates are regular in outline but distinctly overlap each other.

The irregular inflation of the fundus is a characteristic feature. Usually the posterior lateral borders are expanded into lobes of variable size. In some these prolongations are pointed as in *N. bipes,* but more often they are blunt or rounded. Occasionally the fundus is truncated posteriorly, sometimes it is strongly concave. The extensions of the fundus are seldom uniform on the two sides of the shell and are never the same in two individuals. Usually the narrow view of the shell presents an irregular outline. The compression of the shell is seldom uniform, but is always stronger at the fundus border.

The size of the Japanese form ranges from 80 to 100μ in length, including the prolongations of the fundus; from 60 to 80μ in breadth of fundus and from 28 to 60μ in the long diameter of the aperture.

No living individuals were observed.

Heleopera Leidy. *H. picta* Leidy.

Material from Mt. Rokkozan furnished the only species of the genus observed. Under high power the plates are seen to be circular, slightly overlapping. Little foreign material is attached to the shell.

Phryganella Penard. *P. hemisphaerica* Penard.

Frequently observed in many localities.

Campascus Leidy. *C. dentatus,* sp. nov.

In 1877 Leidy discovered *Campascus cornutus* in China Lake, Wyoming, at an altitude of 10,000 feet. Apparently the species has not been observed since that time.

More recently Penard described two species of the genus, *Campascus triqueter* and *Campascus minutus,* from the deep lakes of Switzerland. In both species described by Penard the fundus is without the horn-like prolongations of the form observed by Leidy. *Campascus minutus* was reported by Wailes in 1912 from the New York water-supply drawn from Croton Lake Reservoir.

The form under consideration, which is apparently a new species, was found in the ooze taken from the rocks along the shore of Lake Hakone, Japan, in August, 1912.

The description follows: Shell of yellowish, chitinoid material similar in general outline to *Campascus cornutus.* Under high power the shell has the appearance of being distinctly punctate. In some individuals the punctae are arranged in a regular diagonal manner, in others there is no regularity about the arrangement. In no specimens examined can outlines of plates be detected even with the oil immersion lens.

The neck is short and sharply bent, nearly at right angles to the long axis of the shell. The circular aperture is bordered by a thin delicate membrane of approximately 4μ in breadth.

A number of short, blunt, tooth-like prolongations are present on the posterior border of the fundus. From three to seven of these processes are usually present. They vary in size and when numerous give an irregular, crenulated appearance to the posterior edge of the fundus, when the broad side of the shell is viewed.

In Leidy's species the two horns are directed laterally and posteriorly, their tips not projecting beyond the posterior border, giving the fundus a rounded outline when the narrow side of the shell is observed. In this species the teeth-like points are directed backward and project beyond the border, giving the fundus the appearance of terminating in a spine when the narrow side of the shell is seen.

Leidy records the size of *Campascus cornutus* as ranging from 0.112 mm. to 0.14 mm. long by 0.18 mm. broad.

This species of Japan is much smaller. The length of the shell, including the spines and the collar about the aperture, ranges from 60 to 80μ. Breadth of fundus from 50 to 66μ.

Greatest thickness, narrow view, 28μ. Aperture 12μ in diameter.

The living organism was not observed.

Paulinella Lauterborn. *P. chromatophora* Lauterborn.

Empty shells of this very minute form were found in material from the bottom of Lake Hakone and also from shallow lakes on Mt. Rokkozan. The shell is composed of five longitudinal rows of plates and possesses a short neck. The Japan form is very typical.

Cyphoderia Schlumberger. *C. ampulla* Ehr.; *C. ampulla* var. *papillata* Wailes.

The species is very common in Lake Hakone and was found in other localities. Considerable variation in size and also in the arrangement of plates occurs. The plates are usually placed in diagonal rows, but this regularity is not always maintained.

The variety was observed but once and that in material from Lake Hakone.

Sphenoderia Schlumberger. *S. lenta* Schlumb.

Very widely distributed and also very common in Japan. The only species of the genus to be determined.

Euglypha Dujardin. *E. alveolata* Duj.; *E. brachiata* Leidy; *E. filifera* Penard; *E. laevis* Perty; *E. ciliata* Ehr.; *E. armata* Wailes.

A few species of this genus are very abundant in Lake Hakone as well as in other localities. Two species, *E. filifera* and *E. ciliata,* were rarely observed, the others mentioned are common.

Assulina Ehrenberg. *A. seminulum* Ehr.

Observed in material from Kyoto. A very typical form, chocolate-brown in color.

Plagiopyxis Penard. *P. callida* Penard.

Indentified in material from Kyoto. Not common.

Trinema Dujardin. *T. enchelys* Ehr.; *T. lineare* Penard; *T. camplanatum* Penard.

The genus represented by *T. enchelys* is very common in many localities. The other two species were rarely observed.

Class ACTINOPODA Subclass HELIOZOA

Order APHROTHORACIDA

Actinophrys Ehrenberg. *A. sol* Ehr.

Observed in great abundance at Kyoto; rarely seen in other localities.

The following list is a record of the species of Mastigophora and Infusoria identified in material taken from the fresh waters of Japan. Flagellates and ciliates are very abundant in that country, as elsewhere, and the small number of species here listed indicates brevity of observation rather than any dearth in protozoan fauna. The remarkable thing to be noticed is the identity of the Japanese forms with our common American species.

Subphylum **MASTIGOPHORA:**

Class ZOOMASTIGOPHORA

Order HETEROMASTIGOPHORA

Notosolenus Stokes. *N. orbicularis* Stokes.
Anisonema Dujardin. *A. acinus* Duj.

Order MONADIDA

Anthophysa Bory d. St. Vincent. *A. vegetans* Müll.

Order EUGLENIDA

Euglena Ehrenberg. *E. viridis* Ehr.; *E. deses* Ehr.; *E. acus* Ehr.
Phacus Dujardin. *P. pleuronectes* Müll.; *P. longicaudus* Ehr.
Trachelomonas Ehrenberg. *T. hispida* Stein; *T. volvocina* Ehr.; *T. armata* Stein.
Astasia Ehrenberg. *A. trichophora* Ehr.
Distigma Ehrenberg. *D. proteus* Ehr.

Subphylum **INFUSORIA:**

Class CILIATA

Order HOLOTRICHIDA

Coleps Ehrenberg. *C. hirtus* Ehr.
Lacrymaria Ehrenberg. *L. olor* Müll.
Lionotus Wrzesniowski. *L. fasciola* Ehr.
Dileptus Dujardin. *D. gigas* C. and L.

Chilodon Ehrenberg. *C. cucullulus* Müll.
Nassula Ehrenberg. *N. oronata* Ehr.
Loxocephalus Ehrenberg. *L. granulosus* Kent.
Cinetochilum Perty. *C. margaritaceum* Ehr.
Frontonia Ehrenberg. *F. leucas* Ehr.
Paramaecium Müller. *P. caudatum* Ehr.; *P. bursaria* Ehr.
Cyclidium Ehrenberg. *C. glaucoma* Ehr.
Pleuronema Dujardin. *P.* sp. (undetermined).

Order Heterotrichida

Spirostomum Ehrenberg. *S. ambiguum* Ehr.
Stentor Oken. *S. caeruleus* Ehr.; *S. polymorphus* Ehr.
Gyrocoris Stein. *G. oxyura* Stein.

Order Hypotrichida

Oxytricha Ehrenberg. *O. pellionella* Müll.
Stylonychia Ehrenberg. *S. notophora* Stokes.
Euplotes Ehrenberg. *E. charon* Müll.
Aspidisca Ehrenberg. *A. costata* Duj.

Order Peritrichida

Vorticella Linnaeus. *V.* sps.
A number of undetermined species were observed.
Cothurnia Ehrenberg. *C.* sp. (undetermined).

Class SUCTORIA

Sphaerophrya Claperède and Lachmann. *S. magna* Maupas.

Washburn College, Topeka, Kansas.

EXPLANATION OF FIGURES

Plate III

Fig. 1, *Lecquereusia spiralis* Ehrenberg; × 272. From Lake Hakone.
Fig. 2, *Lecquereusia spiralis* Ehrenberg; × 257. From Lake Hakone.
Fig. 3, *Lecquereusia spiralis* Ehrenberg; × 272. From Lake Hakone.
Variations of the species common in Japan.
The aperature is directed almost straight.
Fig. 4, *Lequereusia modesta* Rhumbler; × 225. From Lake Chuzenji.
Fig. 5, *Difflugia bacillariarum* Perty; × 225. From Lake Hakone.
Fig. 6, *Difflugia elegans* Penard; × 195.
Very common. Individuals observed ranged from 60-194μ in length.
Fig. 7, *Quadrulella symmetrica* var. *curvata* Wailes; × 427.
Near the aperture the plates become small and irregular. Rarely observed. From Mt. Rokkozan.
Fig. 8, *Nebela hippocrepis* Leidy; × 198.
Broad view of a shell. From Mt. Rokkozan.
Fig. 9, *Nebela hippocrepis* Leidy; × 198. Narrow view of same.
Fig. 10, *Nebela triangulata* Lang; × 325.
Broad view of a shell. From Lake Hakone.
Fig. 11, *Nebela triangulata* Lang; × 378. From Lake Hakone.
Fig. 12, *Nebela triangulata* Lang; × 354. From Lake Hakone.
Fig. 13, *Nebela triangulata* Lang; × 315. From Lake Hakone.
Fig. 14, *Nebela triangulata* Lang; × 325. Narrow view of a shell. From Lake Hakone.
Variation in the shape of the fundus and in the arrangement of the plates shown in these figures.
Fig. 15, *Campascus dentatus*, sp. nov.; × 370.
Broad view of a shell with the posterior border of the fundus provided with numerous teeth-like prolongations. From Lake Hakone.
Fig. 16, *Campascus dentatus*, sp. nov.; × 390. Broad view of another shell. From Lake Hakone.
Fig. 17, *Campascus dentatus*, sp. nov.; × 390. Broad view of another shell. From Lake Hakone.
Fig. 18, *Campascus dentatus*, sp. nov.; × 390. Narrow view of same. From Lake Hakone.
Fig. 19, *Paulinella chromatophora* Lauterborn; × 1050. From Lake Hakone.

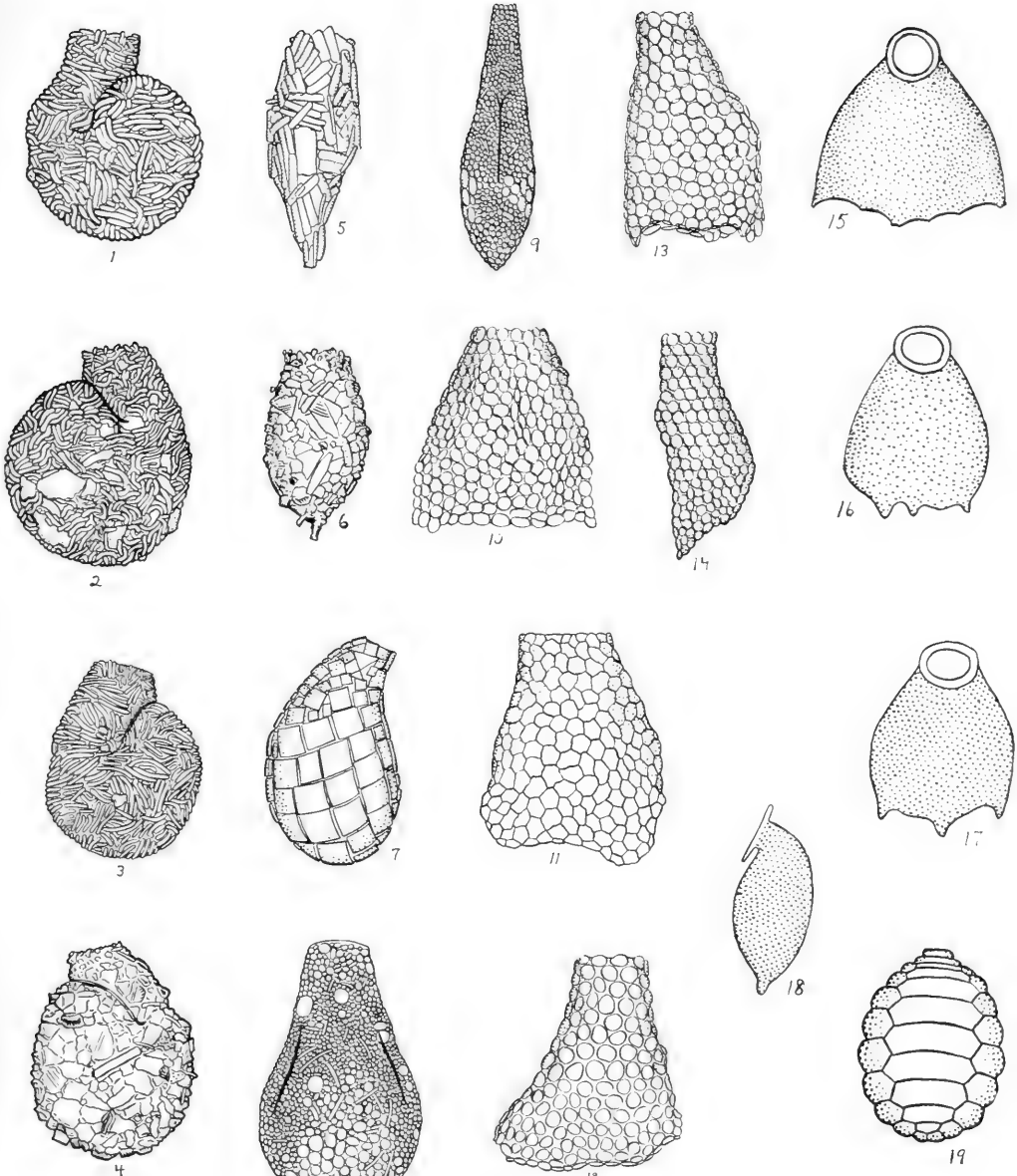

PLATE III.—Japanese Protozoa

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EXPERIMENTAL AMITOSIS IN ONION ROOT TIP

H. E. Jordan

Introduction

My recent study of amitosis in the lining epithelium of the epididymis of the mouse,[1] and in certain other ciliated epithelia, led me to the tentative conclusion that the fundamental causative factor here involved is the partition and consequent destruction of the centrosome in the formation of "basal granules" from which the cilia grow. The suggestion was made that direct cell division is proximally related to factors inducing loss of integrity or impairment of function of the centrosome. Such factors are various, including those originally and recently sugested, namely, intense secretory activity, and disturbed metabolic conditions characterized as "degenerative" (Flemming,[2] Ziegler,[3] vom Rath,[4] et cetera), lack of adequate nutriment (Child,[5] Patterson[6]), insufficient supply of oxygen (Wieman[7]).

To test experimentally this hypothesis a series of experiments were made by growing onion roots in water to which ether was added. Two assumptions, apparently legitimate, are involved: 1) the onion cell has an analogue (indiscernible) of the centrosome of animal cells, similarly concerned in the formation of the mitotic spindle; 2) ether, and other anæsthetics, may be expected to produce a "stupefying" effect upon the "dynamic center" of the cell thus enforcing a direct method of actual multiplication.

The sole result claimed for the investigation is the fact that onion roots continue to grow vigorously in water to which small quantities of ether are added, and that many of the cells are in various phases of undoubted direct division. No originality is claimed either for the hypothesis or for the experimental procedure. I believe, however, that the facts adduced from the study of the epididymis of the mouse offer the strongest histologic evidence yet reported in support of the hypothesis. The experiments were under-

taken simply to test this hypothesis. The same idea must have suggested the experiments of Pfeffer and Nathansohm[8] with spirogyra grown in water with ether, and of Wasielewski[9] with Vicia faba roots grown in chloral hydrate solution.

Nathansohm (1900) claims to have induced amitosis in spirogyra and the desmid *closterium* by transferring karyokinetically dividing filaments to a 1% solution of ether in water. Roots of Phaseolus, Lupinus, Phalaria and Marsilia were similarly treated, but without success in changing cell-division from the indirect to the direct method. Treatment of growing roots of Vicia faba with a 0.7% chloral hydrate solution for various periods is claimed by Wasielewski (1902-1904) to change the majority of cell divisions from mitotic to amitotic. Němec[10] (1904), however, interprets the cell pictures (in roots of *Vicia faba, Allium cepa* and *Pisum sativum*, treated with 0.75% chloral hydrate solution) in terms of nuclear fusions, and disputes their amitotic significance. My experiments with onion root tip grown in ether solution, on the contrary, show unmistakable amitosis. However, in view of the fact that the roots grew vigorously, and that mitoses are always exceedingly rare, and in several instances totally lacking, indisputable healthy amitotic divisions (i. e., apparenty non-degenerative) are unexpectedly relatively rare.

Description of the Experiments

The procedure was simply to place an onion, with stem and roots either absent or just appearing, into the mouth of a small jar so selected for size that the root pole of the bulb was immersed in the solution to a depth of about half an inch. The experiments with controls consisted of three series, with summarized results as follows:

First Series

a) Bulb in 4% alcohol solution.—Neither stem nor roots appeared.

b) Bulb in water unchanged for four days.—Both stem and roots appeared. Of 5 roots examined, two were disintegrating; the remainder showed occasional mitoses in the plerome cells and several doubtful instances of degenerative amitoses in the pleriblem cells.

c) Bulb in water to which a few drops of ether were added thrice daily for two days.—Stem barely developed, many vigorously growing roots appeared. Of 6 roots examined only two showed mitotic figures, limited to the plerome; and all showed occasional direct divisions among the periblem cells.

Second Series (three to eight tips each)

a) Bulb with roots just showing; in water from 10 o'clock A. M. to 4.30 P. M.—Normal; many mitoses both in plerome and periblem; also a few in dermatogen.

b) Bulb in water, unchanged for 4 days.—Mitoses still frequent; a few tips distintegrating.

c) Bulb in water changed twice daily for 4 days.—Normal; numerous mitoses.

d) Bulb in moist cotton 1 day.—Tips of young development; neither mitoses nor amitoses.

e) Bulb in moist cotton 2 days.—Distintegrated.

f) Bulb in water unchanged for one week.—Normal; many mitotic figures.

g) Bulb in water + ether, changed twice daily for 1 day.—Neither mitoses nor amitoses.

h) Bulb in water + ether, changed twice daily for 3 days.—No mitoses; many amitoses.

i) Bulb grown in cotton moistened with water and ether for 4 days.—No growth of either stem or roots.

Third Experiment

a) Bulb in water to which a small amount of ether was added three times daily for 5 days, and allowed to remain in the unchanged water for 2 days longer.—Normal; numerous mitotic figures.

The roots were fixed in Flemming's strong solution.

The sections were cut at from 5 to 10 microns, and stained in iron hæmatoxylin, with and without eosin counterstain.

Description of Normal Root

A brief description of normal conditions seems desirable before proceeding to an analysis of the experimental results of the several

series. The description is based upon an excellent preparation previously made and used for demonstrating mitotic figures in classroom work.

The root-tip contains characteristic cells in the several regions: dermatogen, periblem, plerome, and root-cap. The dermatogen consists of from 2 to 5 layers of very long rectangular cells, with the longest axis parallel to the long axis of the root. The nucleus is pale and finely granular, with one or several nucleoli. The cytoplasm contains large vacuoles and numerous deep-staining spherical granules of various sizes (mitochondria). Some of the cells are in process of indirect division.

The periblem consists of from 7 to 10 rows of small rectangular cells surrounding the central plerome. The longest axis of these cells is generally perpendicular to that of the dermatogen cells. The nuclei are pale staining, finely granular or delicately reticular, mostly with two nucleoli frequently surrounded by a clear halo. The cytoplasm is considerably vacuolated and contains granules similar to those described for the dermatogen. The cells of the layers, more particularly from the third inward and from just above the upper

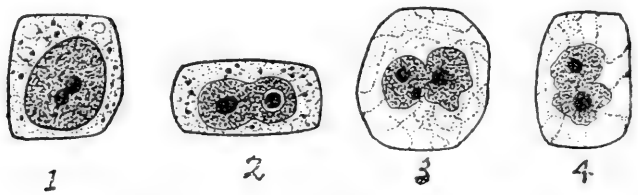


Fig. 1. Sketch of periblem cell from normal root showing early process in constriction of nucleolus. Abundant earlier and later phases also appear. The vacuolated cytoplasm contains deeply staining granules (mitochondria). The nucleus is pale-staining, finely granular, or delicately reticular.

Fig. 2. Typical rectangular bi-nucleolate cell of periblem of normal root. One of the nucleoli is surrounded by a clear halo, probably a fixation artefact.

Figs. 3 and 4. Periblem cells from root undergoing early degenerative changes. The cytoplasm contains huge vacuoles, and lacks mitochondria. The nuclear wall is irregular and apparently suffering an equatorial constriction closely simulating, if not actually, a direct division. Excessive number of nucleoli, i. e., more than two is a common condition in the cells of these tips.

limit of the root-cap, show large numbers of nucleoli at all phases of constriction and separation in the process of the formation of binucleolate nuclei (Figs. 1 and 2). The appearance is exactly that of Remak's classic illustration of the initial step in amitosis. However, the further steps, viz., nuclear and cytoplasmic fission, nowhere appear; and mitoses at all phases are very abundant.

The plerome consists of a variable number of layers. The cells are long rectangular, relatively huge rectangular, and approximately square, in shape. The nuclei are large oval or spherical, mostly with deep-staining coarse reticulum, and with one or two chromatic nucleoli, sometimes appearing achromatic. The cytoplasm contains smaller vacuoles than in the periblem and dermatogen cells and relatively fewer mitochondria. Mitoses are most abundant in this portion. Two chromatic nucleoli are frequently present even at the segmenting spireme stage, of irregular oval shape but with sharp contour.

The root-cap contains larger and smaller polyhedral cells with enormous vacuoles in the cytoplasm and very sparse mitochondria, and pale granular nuclei with one or generaly two nucleoli. These cells are only rarely seen in mitosis in this preparation.

The points of special significance in normal root tip for this study are: 1) absence of amitoses; 2) great abundance of mitoses, especialy in plerome; 3) nucleolar constriction in, and binucleolate character of, the periblem cells; 4) presence of mitochondrial granules (an index of virility); and 5) general pale-staining, finely granular, character of the periblem nuclei.

Analysis of the First Series of Experiments

The non-appearance of roots or stem on the bulb in the 4% solution of alcohol is interpreted to mean that this solution was too strong to permit development. Since the experiment was not repeated with weaker solutions the interpretation must be tentative; but since this is the only complete failure of development in the several series (save one with bulb in cotton moistened with ether solution) it is very plausible. The reason for not further experimenting with alcoholic solutions at this time was the fact that positive results were obtained with the ether solutions.

The roots of the bulb grown in water unchanged for four days differed somewhat from normal, and several were in the later stages of disintegration. Mitoses are numerous in the plerome cells, but practically absent in the periblem cells. Mitochondrial granules are relatively sparse and pale-staining. Relatively more cells have two nucleoli; a number have three (Fig. 3) and even four nucleoli. The periblem nuclei are frequently irregular in outline, with numerous blunt processes; a few may possibly be in process of amitosis (Figs. 3 and 4). On this bulb the stem grew very vigorously. Cytologic appearances must probably be interpreted in terms of early degeneration, involving possibly slight amitotic division.

Roots of bulbs grown in a 3% aqueous solution of ether grew very vigorously, while the stem developed but little. This result seemed to indicate a stimulating effect to root formation, causing indirectly a retardation of stem growth. The jar with bulb was covered under a larger jar to prevent excessive volatilization of the ether. When uncovered as in the later experiments this differential growth of roots and stem was not so evident. The roots have a perfectly healthy appearance, in section in all respects like the normal except that mitoses are almost, and in some tips entirely, lacking even in the plerome cells. Amitoses are abundant in the periblem cells (Figs. 5 and 6), usually appearing in groups of four or eight. Many of these nuclei have an irregular contour with short pseudopodial processes like in the foregoing set of roots. Only rarely can the final process of the formation of a wall between the

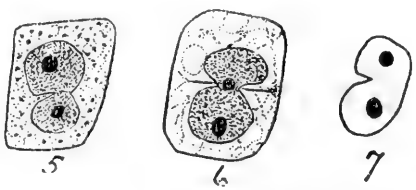


Fig. 5. Periblem cell from root grown in 3% ether solution (first set of experiments), showing early stage in amitotic division.

Fig. 6. Similar cell, showing a later phase of direct division, including the formation of a new cell membrane between the separating daughter nuclei. The cytoplasm contains large vacuoles and lacks mitochondria, in which respects it resembles a degenerating cell.

Fig. 7. Diagram of frequent type of nucleus showing character of initial phase of nuclear direct division.

amitotic moieties be seen (Fig. 6). Many nuclei show a sharp cut at one point on the surface (diagram, Fig. 7), the initial step in the nuclear constriction. This appearance is practically lacking in the previous set.

The number of bi-nucleolate cells does not seem relatively larger than in the normal or degenerating tips. However, multi-nucleolate cells are absent. No significance can be attached to the bi-nucleolate nuclei, from the standpoint of amitosis, since these are almost equaly abundantly present both in normal and degenerating tips. Still, when followed by nuclear fission, as occasionally in tips grown in ether solution, the nucleolar fission represents the initial step in amitosis.

There remains no question, I believe, that true amitosis occurs in these tips, and as the result of ether in the water; but whether this result is direct (i. e., specific, the ether acting anæsthetically upon the astral system) or indirect (i. e., due to abnormal environmental conditions produced by the ether), must remain uncertain. However, the fact that undoubted amitoses are relatively much more abundant in the tips grown in water with ether than the doubtful ones in the unchanged water speaks in favor of a direct retarding influence to centrosomal activity. This conclusion is further strengthened by the fact that the roots grew vigorously; and that no cytologic indications of degeneration, beyond a number of irregular nuclei, appear. The result is disappointing, however, in that the amitoses are unexpectedly rare in view of the rapid growth and the absence of mitoses. It cannot be asserted with full surety that growth was entirely by amitosis, since a few mitoses appear in the plerome cells; and, moreover, the possibility remains that the tips were cut at the interval between mitotic waves. But if this were the true explanation of the absence of mitoses, not all of the roots would be expected to show substantially the same condition. It seems then that amitosis plays a considerable part in the growth of root tips in water with ether, and that it does not necessarily signify degeneration since the tips after two days are still vigorous and normal. That the complete amitotic process is consummated, though the final step is difficult to demonstrate, is further indicated by the complete absence of bi-nucleolate cells.

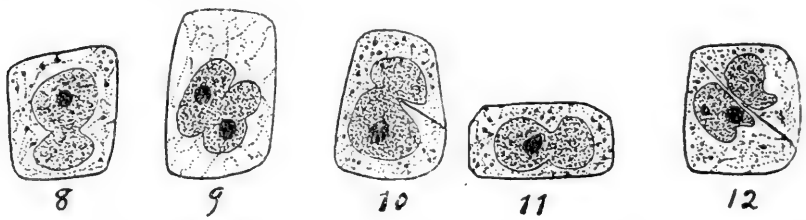
It seemed possible that the degeneration and incidental probable amitosis of the roots grown in unchanged water might be due to the presence of the extract of onion held by the water; also, this method of sprouting bulbs is so far from normal that only degeneration phenomena (including amitosis) could perhaps be expected. To check these uncertainties, and to further test the influence of ether on mitotic proliferation, the second set of experiments was devised.

Second Series of Experiments

Growth in moist cotton gave wholly negative results as the above summary shows. This evidently makes a most unfavorable growth medium.

The roots grown in water changed twice daily were normal.

Those grown in unchanged water, even after an entire week, were still vigorous and essentially normal. Thus extract of onion appears to have no inhibitory or deleterious effect, at any rate if allowed to volatilize freely. In the previous experiment the bulb fitted more closely into the mouth of the jar. The cause of the degeneration in several roots in the first series of experiments remains obscure.



Figs. 8, 9 and 10. Periblem cells from roots grown in ether solution (second set of experiments), showing three stages in the nuclear constriction; in Fig. 10 a new cell membrane is forming and has progressed into the depth of the constriction on the right.

Figs. 11 and 12. Periblem cells from the same set showing initial and final stages in direct division.

The bulb grown in the ether solution again sprouted roots, showing the identical condition described in the first series (Figs. 8 to 12).

Third Experiment

The third experiment was planned for the purpose of testing whether tips induced to presumable amitotic growth by ether could again revert to mitotic growth on resumption of normal conditions. With this end in view a bulb was placed as above in a 3% solution of ether (ether being added thrice daily) for 5 days, and then allowed to continue development for two more days without further addition of ether. Six roots were cut and fixed at the end of the seventh day. All except two which were distintegrating were apparently normal and the majority contained abundant though frequently atypical mitotic figures. The result of this experiment indicates that the direct cell division in the roots developing in the ether solution does not necessarily lead to degeneration. Significantly, too, several of the roots showed a few bi-nucleate cells; as if the amitotic process had been halted short of consummation at the disappearance of the ether from the water.

Conclusion

Onion root-tips grown in appropriate solutions of ether (approximately 3% in water) show an almost complete absence of mitotic figures, and a considerable number of periblem nuclei in process of direct division. Amitosis is not present in roots grown in pure water, while mitoses are abundant. Ether would appear to have a "stupefying" effect upon the astral apparatus, preventing karyokinetic cell division. Certain appearances (e. g., pale periblem nuclei of irregular contour) suggest degeneration; but roots similarly treated with ether for several days and then allowed to develop for several more without further addition of ether, proceed to grow normally and show abundant mitoses. Thus the amitosis seems capable of reversion to mitotic type. These results confirm those of Pfeffer and Nathansohm with spirogyra and closterium, and those of Wasielewski with roots of Vicia faba grown in chloral hydrate solution. Wasielewski, however, could only report a majority of direct, as compared with indirect, divisions in Vicia faba; and my own results are disappointing in that, in view of the almost total absence of mitoses, undoubted amitoses are rare. Concerning a certain small number, however, there can be no doubt. It must

still remain uncertain whether these represent early indications of a reversible degenerative process due to unfavorable environment, or the result of a direct influence on the part of the ether upon the achromatic spindle complex. The apparent selective action upon the periblem cells also remains obscure. Whether degenerative in significance, as seems more probable in view of certain cytologic correspondences above detailed, or otherwise, the amitosis present in etherized roots seems clearly the result of a superior sensitiveness on the part of the centrosome and the astral associates to untoward environmental influence.

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SUMMARIES IN MICRO-BIOLOGY

For some months the Secretary has been planning to secure for this Journal and its Department of Summaries, a series of papers from biologists dealing with the chief groups of microscopic plants and animals. It has not been the purpose to present a complete survey of any of the groups. The wish has been rather to bring together in one article a statement of the following things:—general biology, the method of finding, the methods of capture and of keeping alive and cultivating in the laboratory; how best to study; the general technic; the most accessible literature; and a brief outline of the classification, with keys for the identification of at least the more representative genera and species of the micro-organisms likely to be found by the beginning students in the United States.

It has been felt that the getting together of such data as this, while not a contribution to science, would be a contribution especially to isolated workers and to teachers and students in the high schools and smaller colleges.

Papers have already appeared treating the aquatic Oligochetes, the Melanconiales and the Rusts. The following is the fourth paper of the series. It is proposed to have such synopses from time to time until the more common American species of such groups as the following have been covered: The Blue-green Algae, Conjugating Algae, Diatoms, other Green Algae, Downy Mildews, Yeasts, Powdery Mildews, Hyphomycetes, Smuts, Rhizopods, Infusoria, Turbelaria, Bryzoa, Water Mites, Entomostraca, etc.—[Editor.]

THE BLACK MOULDS (*Mucoraceae*)

LEVA B. WALKER

The Mucoraceae receive the name "Black Moulds" from the fact that in a number of the most conspicuous genera the fruiting bodies and older hyphae are dark colored or "black." A young growth of any of these fungi is, however, always colorless. They are largely saprophytic and are found abundantly on decaying organic matter, especially on dung, and in the soil as common soil fungi. The parasitic forms live upon other mucors or upon basidiomycetes. Almost all are easily cultivated on bread, on dung or on ordinary culture media (either directly or by culturing the host and parasite together) if bateriological apparatus is at hand.

1. Plant Body

The Mucoraceae form a well-defined group. The plant body, as is true for almost all phycomycetous fungi, is siphonaceous, cross walls being few or none, always coenocytic. The protoplasm in young growing filaments shows characteristic movement in a "glacier-like" fashion. The mycelium may be superficial, developing rhizoids that penetrate the substratum, or it may develop almost entirely within the substratum.

2. Sexual Reproduction

The most uniform character in the Mucoraceae is the production of zygospores. The zygospores are developed by the union of cells from the same filament or from other filaments. First very much enlarged branches (progametes) branch off from two adjacent filaments (Plate IV, Fig. 1, a), a cell is cut off from the end of each progamete, these end cells becoming the gametes (Fig. 1, b (x)), the enlarged supporting cell being called the *suspensor* (Fig. 1, b (y)). The gametes fuse (Fig. 1, c) by the absorption of the wall between the gametes, and a thick wall is built up around the fertilized cell, which is then called the zygospore. While zygospores are known for most of the species of the Mucoraceae, they are rarely found. When they do appear in cultures they appear in great abundance. The conditions necessary for the production of zygospores has been the subject of many researches, the most extensive of which are those of Blakeslee, who has shown definitely that the Mucors are separable into two distinct types which he terms *homothallic* and *heterothallic*. In homothallic forms the gametes are produced from branches of the same filament and zygospores are usually abundant in nature wherever the fungus is found. In the heterothallic forms the gametes must be produced from separate strains (termed for convenience + and —) of the fungus which often differ so greatly in appearance that they might easily be taken for separate species or at least varieties. Extensive experiments made by planting + and — strains of many Mucors together show that when a + and a — of different species are planted together the progametes will form (but will not form zygospores), but that when a + and a + or a — and a — are planted together no such progametes are formed. The + strain is usually a little more vigorous than the —, and in some cases the gametes are larger, so we can well think of the + strain as female and the — as male. In heterothallic forms the zygospores are rarely found, as either the + or the — is rare. The germination of the zygospores has been observed in relatively few cases, but where observed takes place much as shown in Fig. 3, l. Zygospores germinate only after a resting period.

3. Asexual Reproduction

Sporangiospores—The sporangiospores (usually referred to

simply as *spores*) are typically formed in sporangia which are produced on erect well-differentiated hyphae known as *sporangiophores.* The sporangia are separated from the sporangiophores by a cross partition which usually rounds up into the sporangium, forming a *columella* (Fig. 1, f). The outer wall of the sporangium is usually delicate, dissolving in water, or fracturing easily so that in examining material in water mounts under the microscope the spores are often seen surrounding the columella, the only remnants of the outer wall being seen at the point of its attachment to the columella. The sporangia are in most cases evident and many spored, but in one tribe they are reduced seemingly to one spored sporangia and the one celled sporangia are usualy called "conidia." In another tribe the spores are arranged in a single row in a sporangium which breaks down so readily that it is rarely distinguishable and gives the appearance of a chain of "conidia."

The asexual reproduction as above described is always the most abundant form of reproduction and some forms are only known by their asexual reproduction. For this reason the keys which will follow are based upon the sporangial reproduction. The spores are capable of germination at once (Fig. 3, above i), but will usually remain viable for an indefinite period.

Azygospores—These are often found in cultures of Mucors, they usually appear much like the zygospores, but are formed without the union of gametes.

Chlamydospores—Thick-walled spores, known as chlamydospores, are often found in the main vegetative filament, or on the ends of filaments (Fig. 3, i, k). They may germinate at once or after a resting period.

4. Systematic

The Mucoraceae comprise a group of about forty described genera and over three hundred described species. Probably most of these are present in our flora. Only a few of the most typical and abundant genera and species will be mentioned here.

KEY TO THE TRIBES OF MUCORACEAE.

A. Reproduction asexually by spores contained in evident sporangia.
   I. Columella present.
      a. Sporangia many-spored, generally of one kind or if two kinds the smaller irregularly disposed on the main sporangiophore.
         1. Membrane of sporangium easily dissolved or fractured ..... *Mucoreae (I)*
         2. Membrane of sporangium usually solid, persistent..... ..... *Piloboleae (II)*
      b. Sporangia of two kinds, the larger many spored, the smaller few spored and formed on the ends of regularly branched sporangiophores ..... *Thamnidiae (III)*
   II. Sporangia without a columella..... *Mortierelleae (IV)*
B. Reproduction asexually by so-called "conidia" produced either solitary or in chains.
   I. "Conidia" solitary, produced upon the ends of usually much branched "conidiophores" ..... *Chaetocladiae (V)*
   II. "Conidia" in chains, produced in head-like masses upon sterigmata at the ends of "conidiophores"..... *Cephalideae (VI)*

I. TRIBE MUCOREAE

Sporangia generally of one kind with a columella and a membrane that dissolves or fractures easily. Smaller sporangia (sporangioles) with persistent membranes occur very rarely and in such cases are disposed without order upon the main sporangiophore. Zygospores naked or surrounded by appendages.

KEY TO GENERA.

I. Sporangiophores fasciculate on a rhizoidiferous stolon.
   1. Sporangia globose; zygospores unprotected.....Rhizopus
   2. Sporangia pyriform; zygospores protected by flexuous unbranched outgrowths from the suspensors..... *Absidia*
II. Sporangiophores emerging solitary from the mycelium, no rhizoidiferous stolons.
   1. Sporangiophores unbranched, or not dichotomously branched.
      a. Mycelium of one kind.
         1. Zygospores unprotected.
            a. Gametes about equal (heterothallic or produced from widely separated parts of the mycelium)..... *Mucor*
            b. Gametes unequal (produced from closely related branches of the same filament)..... *Zygorrhynchus*
            c. Zygospores protected by spiny branched outgrowths from the suspensors ..... *Phycomyces*

b. Mycelium of two kinds, the one colorless in the substratum, the other aerial, brown and spiny, producing sporangiophores and zygophores .....*Spinellus*

2. Sporangiophores repeatedly dichotomously branched. Zygospores produced between dichotomously branched hyphae.....
.....*Sporodinia*

Rhizopus (=Ascophora)—Saprophytic fungi, the hyphae non-septate and much branched, forming long stolons and rhizoids. Sporangiophores clustered at the nodes (Fig. 1, e) above the rhizoids. Sporangia spherical containing many spores. Zygospores spherical or nearly so with a thick, warty dark-brown wall: heterothallic.

R. *nigricans* Ehrb. The stolons far spreading, often 1-4 cm. long, covering the substratum with a cobwebby growth which is at first colorless, but finally brown. Rhizoids much branched, colorless at first, finally becoming brown. Sporangiophores mostly in clusters of 3-5 (seldom single), unbranched 0.5-4 mm. high. Sporangium and columella (Fig. 1, f). Sporangia 100-350μ in diameter. Spores irregularly globose or broad oval 6-17μ with longitudinal ridges, light gray (Fig. 1, g). Zygospores 160-220μ in diameter, brown-black, opaque, warty (Fig. 1, d).

On all kinds of organic matter. It is our most common black mould and will usually appear in a few days upon moist bread or any organic substance when placed in a moist chamber. Cultures can always be easily obtained by breaking open a sweet potato that has rotted with a soft rot and placing it in a moist chamber for a few days. The rot is caused by the fungus. It also causes large proportion of the rot of strawberries. In growth upon these hosts the stoloniferous habit is often not seen.

Absidia—Saprophytic fungi. Mycelium stoloniferous; sporangiophores in groups produced only on the tips of the arched internodes (Fig. 2, a). Sporangia pyriform (Fig. 2, c). Columella blue-black. Zygospores protected by flexuous circinate outgrowths from one or both suspensors (Fig. 2, b). Both heterothallic and homothallic forms known.

A. *caerulea* Bainier. Vegetative hyphae blue-violet, sporangiophores up to 25 mm. in length. Sporangia pale-violet to brown bearing many pale-violet spores 4-7μ. Columella hemispherical or ab-

conical, often surmounted by a nipple (Fig. 2, d). Zygospores 60μ in diameter with suspensors provided with 10-20 long slender circinate appendages; heterothallic.

On dung, in humous soil, etc.

MUCOR. Saprophytic fungi. Mycelium of one kind, largely penetrating the substratum, without rhizoidiferous stolons. Sporangiophores produced singly (Fig. 3, a-d). Zygospores unprotected. Gametes about equal, heterothallic or at least produced from widely separated parts of the mycelium. (Over one-third of the described Mucoraceae belong to this genus.)

Key to Species

I. Sporangiophores not branched.
   a. Sporangiophores not exceeding 1 cm. in length.....*M. hiemalis*
   b. Sporangiophores 2-15 cm. long.....*M. mucedo*
II. Sporangiophores branching indefinitely (Fig. 3, b).....*M. racemosus*
III. Sporangiophores branched in sympodial cymes.
   a. Sporangiophores non-erect ending in a large sporangium and producing a short distance below more or less closely clustered branches which bear sporangia (Fig. 3, c).....*M. botryoides*
   b. Sporangiophores circinate (Fig. 3, d).....*M. circinelloides*
   c. Sporangiophores straight, not circinate columella spinescent (Fig. 3, f) .....*M. plumbeus*

M. *hiemalis* Wehmer. Mycelium a bright gray, sporangia green to yellow-black 50-80μ in diameter. Columella globose when young becoming somewhat elongated. Spores regularly ellipsoidal 4-10x2.5-5μ. Chlamydospores numerous in the substratum, irregular pyriform, barrel shaped, etc. (Fig. 3, k). Zygospores globose 70-100μ black warty; heterothallic.

Common in soil and on organic matter.

M. *mucedo* (Linne) Brefeld. Sporangiophores erect, rigid simple 2-15 cm. high becoming brown when old. Sporangia spherical (Fig. 3, e) 100-200μ becoming brown when old, covered with slender crystals. Columella high-cylindrical to globose (Fig. 3, g). Spores twice as long as broad 6-12 by 3-6μ, smooth weak yellow to colorless. Zygospores globose 90-250μ in diameter, black, heterothallic.

Common in soil or on organic matter.

M. *racemosus* Fresenius. Sporangiophores 5-40 mm. long, rigid, irregularly branched (Fig. 3, b) in mass a dirty light yellowish color. Sporangia spherical 20-70μ in diameter, dirty yellow to brownish, the sporangial wall smooth, not dissolving in water, but breaking open easily. Spores hyaline to dirty yellow ellipsoidal to globose 4-8x4-10μ smooth. Zygospores globose 70-85μ in diameter, brown warty, heterothallic. Chlamydospores abundant even on the sporangiophores; globose to oblong (Fig. 3, i) 10-20x25-30μ wall smooth, contents containing oil drops.

Common in soil and on organic matter.

M. *botryoides* Lendner. Sporangiophores as shown in Fig. 3, c, 1.5 cm. in height. Sporangia globose, clear gray, the walls diffluent in water. Terminal sporangium 80μ in diameter; columella globose (Fig. 3, h). Spores globose 4-10μ in diameter, uneven. Chlamydospores lemon shaped 16-22x10-16μ.

Fairly common in soil.

M. *circinelloides* Van Tieghem. Sporangiophores sympodially branched (Fig. 3, d), branches 5-6 often appearing as sessile, brownish. Sporangia globose variable in size, those of the larger having diffluent walls, while those of the smaller are persistent. Spores 3-4x5-6μ smooth, weak gray in mass. Zygospores globose red-brown with long thorn-like pointed warts that are streaked longitudinally; heterothallic.

Fairly common in soil and on organic matter.

M. *plumbeus* Bonorden. Sporangiophores rigid, erect, straight, up to 1 cm. high, branched, all branches ending in sporangia. Sporangia globose, small, up to 100μ in diameter, dark brown to black at maturity, finely spiny, membrane dissolving leaving a basal collar. Columella long cylindrical to pyriform with one or more spines on the summit (Fig. 3, f). Spores globose, yellowish brown with irregular folds. Chlamydospores as in M. racemosus.

Fairly common in soil and on organic matter.

ZYGORRHYNCHUS—Separated from mucor by the gametes, which are unequal and arise comparatively close together, almost invariably originating from a single aerial hypha (Homothallic).

Z. *vuilleminii* Namyslowski. Sporangiophores flexible, septate variable in length. Sporangia globose 30-70μ in diameter covered

with needles of calcium oxalate, membrane diffluent only when old. Columella broader than high (Fig. 4, b). Spores 2x4μ (Fig. 4, d). Chlamydospores 40x14μ, usually in chains. Zygospores brownish, covered with tubercles 2-3μ high (Fig. 4, a and c). Azygospores frequent, smaller than zygospores.

Z. *moelleri* Vuillimin. Differs only in size of spores. Spores 3x5-7μ.

Both species are found in soil and on organic matter.

Phycomyces—Saprophytic fungi; sporangiophores simple arising singly metallic-green or olive, terminated by a large sporangium; sporangia many spored, the membrane dissolving; columella pear shaped (Fig. 5, c). Zygospores dark brown, protected by dichotomously branched spiny outgrowths from the suspensors.

P. *nitens*. Kunze. Sporangiophores 7-30 cm. high (Fig. 5, a). Sporangia about 1 mm. in diameter; spores ellipsoid 16-30x8-15μ (Fig. 5, b). Zygospores round, 300μ thick (Fig. 5, d), typically heterothallic.

On oily or decaying organic matter, especially on old bones or other oily matter.

Spinellus—Differs from Mucor only in the mycelium being of two kinds. (It is often included in the genus Mucor.) The mycelium in the substratum is flexuous, smooth and colorless, that in the air brown, and covered with spines. Sporangiophores and zygospores are both produced only on the aerial mycelia (Fig. 6).

S. *fusiger* (Lk.) Van Tieghem. Sporangiophores single, unbranched, rigid below bulbous inflated (Fig. 6, e), blue-gray to chocolate-brown at maturity, 0.1-6 cm. high; sporangia black at maturity 180-300μ in diameter, with a sub-conical columella (Fig. 6, b). Spores spindle shaped, brown 30-40x9-12μ (Fig. 6, d). Zygospores dark brown 180-400μ thick; homothallic (Fig. 6, c).

Common, parasitic on agarics.

Sporodinia (Syzygites)—Vegetative filaments delicate, penetrating the substratum. Aerial filaments dichotomously branched producing sporangia and zygospores. Sporangia spherical with hemispherical columella. Zygospores spherical, smooth, homothallic (Fig. 7; Plate V).

S. *grandis* Lk. Sporangiophores repeatedly dichotomous, septate (Fig. 7, a and b). Sporangia pale red or orange when young, at maturity brownish or blackish brown. Spores round or ellipsoid 11-40μ. Zygospore mycelium brown, the ends tapering (Fig. 7, c).

Common in nature upon decaying Boleti and other large, fleshy fungi, but can readily be grown upon bread or other organic media.

II. TRIBE PILOBOLEAE

Sporangia of one kind only with membrane for the major part solid, persistent, of a very dark blackish color, or swelling only toward the base. Sometimes the sporangium dissolves, leaving the columella, while more often it is forcibly thrown off with the columella and opens only after swelling of the membrane. Zygospores naked (Fig. 8, e).

PILOBOLUS (=Hydrogera)—This is the only genus found in our flora. In this genus the sporangiophore is swollen above and the sporangium thrown off.

Key to Species

1. Swelling at top of sporangiophore ovoid.
   a. Sporangiophore slender, spores oval.....*P. crystalinus*
   b. Sporangiophores short and thick, spores globose.....*P. oedipus*
2. Swelling at top of sporangiophore almost spherical .....*P. roridus*

P. *crystalinus* Tode. Sporangiophores 5-10 mm. long (Fig. 8, a), columella conical (Fig. 8, b). Spores 5-10x3-6μ, colorless (greenish yellow in mass).

On dung (usually appears on horse dung left for a few days under a bell jar).

P. *roridus* Persoon. Sporangiophores 1-2 cm. high (Fig. 8, d), columella rounded, short. Spores 8-6x3-4μ, colorless (pale yellow in mass).

On dung.

P. *oedipus* Mont. Sporangiophores 1-3 mm. high (Fig. 8, c), contents orange red, columella conical, reaching almost to the summit of the sporangium. Spores round, 10-14μ, orange.

On excrement of animals, on mud, on decaying algae.

III. TRIBE THAMNIDIAE

Sporangia as in the Mucoreae, but of two kinds: the one many spored, with membrane that dissolves, leaving only a naked columella; the other (sporangioles) few spored with a persistent membrane, often without columella. The sporangioles are produced on the ends of branched sporangiophores, which are formed at regular intervals on the principal sporangiophores. Zygospores as for Mucoreae.

KEY TO GENERA

1. Primary sporangia with, sporangioles without, columella...*Thamnidium*
2. Both kinds of sporangia with columella.....*Dicranophora*

THAMNIDIUM—Sporangiophores erect, principal sporangia terminal on the main branches, with columella; sporangioles on side branches, without columella.

T. *elegans* Link. Sporangiophores (Fig. 9, a) 0.5-3 cm., occasionally 6 cm. high, the branching very variable. Sporangia 100-200μ in diameter, white, with large columella, many spored (Fig. 9, d). Sporangioles globose, small, white 8-16μ in diameter, mostly 4 spored (Fig. 9, b). Spores 8-10x6-8μ smooth, weak gray brown. Zygospores globose, black, warty (Fig. 9, e).

On dung, in soil, on decaying plant parts, etc.

T. *amoenum* (Preuss) Schroet. Differs from T. *elegans* in that the sporangioles are produced on the coiled tips of lateral branches (Fig. 9, c). Sporangia are brownish, with a large egg-shaped columella. Spores 6-8x4-6μ.

On decaying wood, dung, etc.

DICRANOPHORA (Fig. 10)—This genus is rarely found, but is mentioned because of its having gametes entirely unequal, homothallic (Fig. 10, a), and because of its peculiar sporangiophores (Fig. 10, a-b).

IV. TRIBE MORTIERELLEAE

Sporangia without a columella (Fig. 11, a-b), membrane dissolving readily. The zygospores surrounded by a densely interwoven mass of hyphae which grow from the suspensors, and from the branches from which they arise (exterior Fig. 11, d, section Fig. 11, e).

Only one genus and one species will be mentioned, *Mortierella polycephala,* Coemans. Mycelium much branched and stolon-like, fusing with neighboring hyphae to form a network, septate when old. Sporangiophores erect 250μ high, in groups of 5-20, swollen at the base, tapering to the top, terminating in a large sporangium, and on the upper portion bearing 2-10 short branches terminating in small sporangia. Sporangia round, white 4-20 spored, spores 10-12μ, with a large, glistening oil drop.

On dung, decaying fungi, etc.

V. TRIBE CHAETOCLADIAE

Sporangia and "conidia" both produced or only "conidia" (the conidia are to be regarded as reduced one celled sporangia). "Conidia" formed singly (not in chains) upon the ends of the usually much-branched conidiophores. Zygospores naked. Chlamydospores, round intercalary.

CHAETOCLADIUM—This is the only genus commonly met with. Usually parasitic upon other Mucoraceae, occasionaly saprophytic. Mycelium thin, colorless, forming clusters of short, thick haustoria at point of attachment with the hyphae of the host (Fig. 12, d). Conidiophores creeping, verticillately branched. Conidia produced on the swollen middle portion of the branches, the ends of which are sterile (Fig. 12, b, c).

C. *jonesii* (B. and B.) Fresenius. Conidia round 6.5-10μ, singly, colorless, but blue in mass.

On Mucoraceae (partially saprophytic).

C. *brefeldii* Van Tiegh and Le Mon. Conidia globose or globose elliptical, smooth, colorless 2-5μ.

Parasitic on Mucor mucedo and Rhizopus nigricans.

VI. TRIBE CEPHALIDEAE

"Conidia" seemingly produced in chains on the ends of simple or branched conidiophores. (Really produced in a row in an elongated sporangium which soon disappears.) Zygospores naked.

KEY TO GENERA.

1. "Conidiophores" not swollen at tip.....*Piptocephalis*
2. "Conidiophores" swollen at tip.....*Syncephalis*

PIPTOCEPHALIS—Parasitic on other Mucoraceae by means of filiform haustoria (Fig. 13, b). "Conidiophores" repeatedly dichotomously branched (Fig. 13, a), erect, septate, brownish with age, not swollen at tip. "Conidia" cylindrical or spherical in radial chains clustered on the ends of the branches. Zygospores spherical, naked (Fig. 13, c).

P. *tieghamiana* Matruchot. Conidia spindle-shaped to cylindrical, 4-5x2-2.5μ.

Parasitic on Rhizopus nigricans (rare).

SYNCEPHALIS—Parasitic on other Mucoraceae (or saprophytic). Mycelium of very slender branching and anastomosing filaments, producing numerous clusters of rhizoids which penetrate the host (Fig. 14, i). "Conidiophores," stout, erect, mostly unbranched, enlarged above; "conidia" cylindrical to fusiform, in many radiating chains clustered on the enlarged summit of the conidiophore. Zygospore spherical, naked, rarely produced as a lateral outgrowth from the fertilized cell. Many species are apt to be found, but none very common, so only a key to species will be given.

Key to Species

I. "Conidiophores" erect (Fig. 14, a).
  1. "Conidia" produced directly upon the enlarged end of the "Conidiophore" (Fig. 14, g).
    a. Spores 8-9x3-4μ
      "Conidiophores" 420-720μ high.....*S. sphaerica*
    b. Spores 20-27x7-11μ "Conidiophores"
      very slender 400-475μ high.....*S. tenuis*
  2. "Conidia" produced upon short branches of the enlarged end of the conidiophore (Fig. 14, d, e, f).
    a. Spores cylindric 60-80x5-6μ
      "Conidiophores" 2-3mm. high.....*S. cordata*
    b. Spores rectangular 13-16x7-8μ
      "Conidiophores" 300-350μ high.....*S. pycnosperma*
    c. Spores cylindric 8-10x6μ
      "Conidiophores" 120-150μ high.....*S. nodosa*
    d. Spores cylindric 5-6x3μ
      "Conidiophores" 0.5mm. high.....*S. depressa*

II. Conidiophores incurved (Fig. 14, b and c).
    a) Spores 10-12x4-5μ
      "Conidiophores" 170-200μ high (Fig. 14, c).....*S. cornu*
    b) Spores 7-8x3-4μ
      "Conidiophores" 100-120μ high (Fig. 14, b).....*S. reflexa*

S. *sphaerica* Van Tieghem—On horse dung with Mucoraceae.

S. *tenuis* Thaxter—On sphagnum.

S. *cordata* Van Tieghem—On dung.

S. *pycnosperma* Thaxter—On dung of mice and sheep.

S. *nodosa* Van Tieghem—Parasitic on Mucoraceae.

S. *depressa* Van Tieghem—On horse dung.

S. *cornu* Van Tieghem and Le Mon.—Parasitic on Mucoraceae.

S. *reflexa* Van Tieghem—On dung.

5. Literature

Aside from the general treatment of the Mucoraceae in such publications as Engler and Prantl's "Die Natürlichen Pflanzenfamilien," Saccardo's "Sylloge Fungorum," Rabenhorst's "Kryptogamen Flora," the literature is very greatly scattered. Only a few of the more easily obtained publications in English will be listed.

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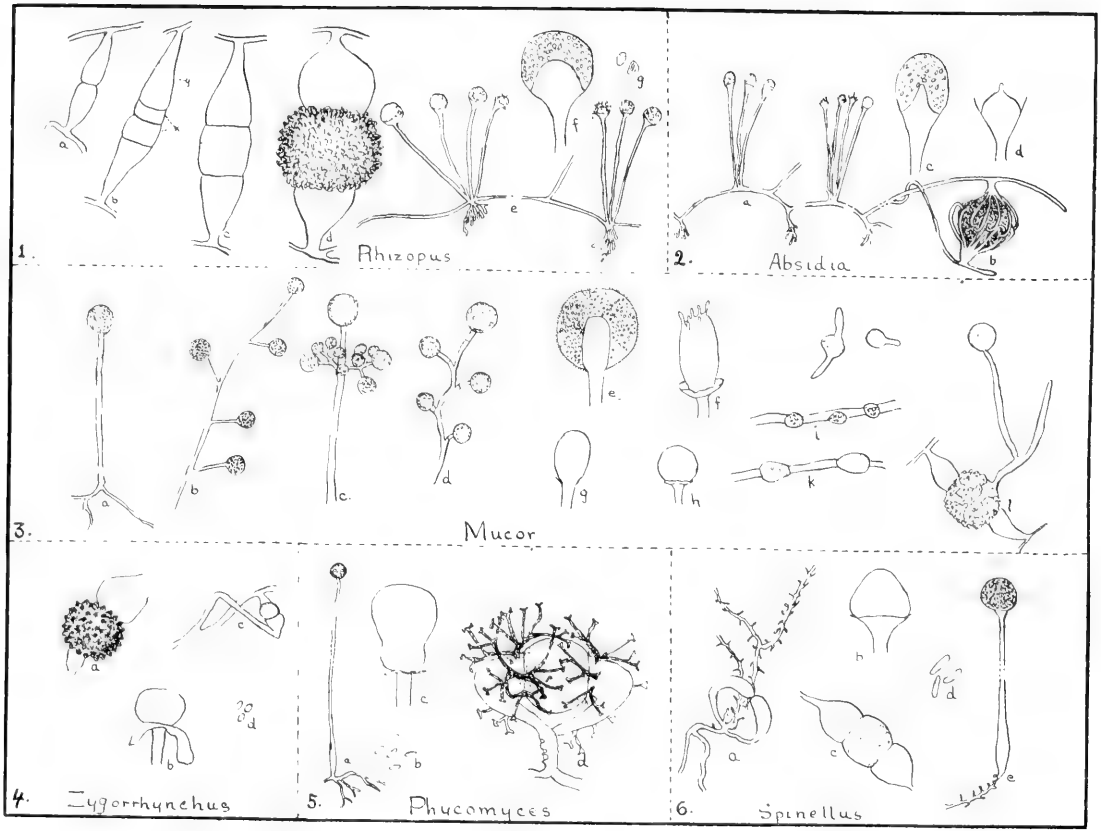


PLATE IV.—Diagrams of Mucoraceae

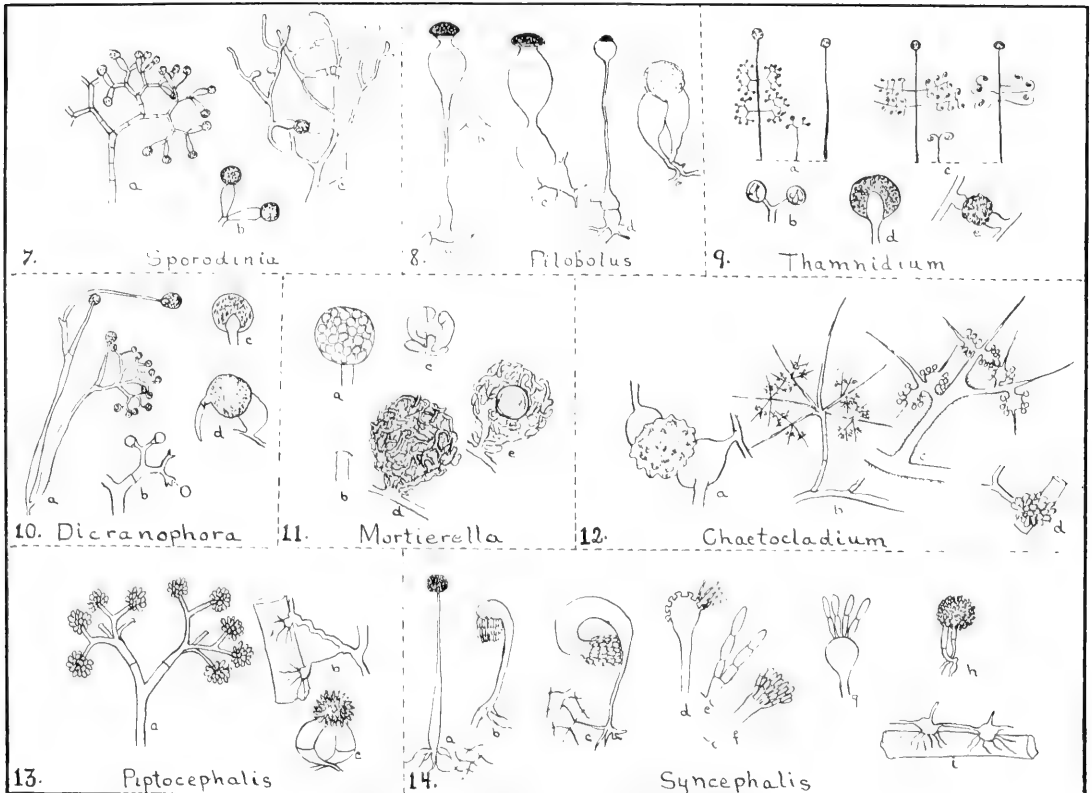


PLATE V.—Diagrams of Mucoraceae

DEPARTMENT OF NOTES, REVIEWS, ETC.

It is the purpose, in this department, to present from time to time brief original notes, both of methods of work and of results, by members of the Society. All members are invited to submit such items. In the absence of these there will be given a few brief abstracts of recent work of more general interest to students and teachers. There will be no attempt to make these abstracts exhaustive. They will illustrate progress without attempting to define it, and will thus give to the teacher current illustrations, and to the isolated student suggestions of suitable fields of investigation.—[Editor.]

Summary of the Elements in the Reproductive Process

Teachers of Biology often have occasion to devise special methods to put before students, in a single view, the various elements in a complex biological concept. Such a device, if successful, is in reality a summary of the essential factors or parts of t' ? process or structure, together with an expression of the relations between the factors, so formulated that the pupil may successfully visualize them in their proper proportions and be conscious of them in his complete synthesis of the concept. Such a device is peculiarly essential with certain classes of pupils who, after an analysis of such a complex, refuse to re-synthesize *all* the elements—but allow one or two major factors to usurp the meaning of the whole. The need of this sort of aid is apparent especially in the study of the evolutionary processes where the comparative element enters largely.

Reproduction is an illustration of such a complex and significant phenomenon in biology. It is so varied in the different groups of plants and animals, and includes or has associated with it so many different elements at the different levels of life that it is almost impossible to bring even the most important of these into a scheme in such a way that the student may grip their interrelations, and it is not possible in any scheme of reasonable complexity to include all the related facts.

The device presented herewith is submitted purely as a pedagogical scheme summarizing the main features of the process of reproduction in plants and animals, and showing at least a portion of the evolutionary tendencies connected with the fundamental func-

tion. It is offered to assist teachers and not as a contribution to knowledge.

The following brief discussion of the major items connected with reproduction, as exemplified by the two series of organisms, will serve to explain and elaborate the heads included in the table (Plate VI).

1. *The essential nature of reproduction,* no matter how simple nor what additional processes and complications may be introduced, is *division.* The divisions may be equal or unequal, may be of single-celled organisms or of complex; but without any exception reproduction always involves the division of parental material to make offspring. New individuals are thus formed at the expense of the old. It is always in contrast with assimilation and growth, and means a sacrifice of the individual structure that has been builded up by these processes. This reproduction or division resulting from growth is due apparently to some stimulus which is normally brought on by the accumulation of internal materials and the near culmination of internal processes and powers which we describe by the term maturity. The exact nature of these stimuli we do not know. (See first column of chart.)

2. *Primary Kinds of Division* (*Reproduction*). There are two main types of parental division, depending on the complexity of the organisms (second column):—

(a). In unicellular organisms reproduction is a matter of nuclear and cell division merely. Such daughter cells separate and lead individual lives. The division of one cell into two or more cells is at the same time the division of an individual one-celled parent organism into two or more individual offspring. The cell being the body of the organism, reproduction is at once a bodily division and a nuclear or cell division. This is reproduction at its simplest. Clearly in such a case as this the daughter organism, which is a small cell, reaches maturity by a simple process of growth into a large cell, whereupon reproduction may occur again, when the stimulus of maturity becomes operative.

(b). By far the greater number of our plants and animals are, however, multicellular in their adult stage. They have reached this condition by a long series of nuclear and cell divisions in which

the cells *did not separate* into distinct individuals, but remained together as parts of a more complex individual. Division of such an organism as this is a somewhat different thing from what was described in (a). The many-celled organism may divide bodily into two or more smaller, but many-celled, offspring. This is analogous to the division in (a) in that it is a mass division. It differs from (a) in that it is not at all a cell division.

Again the multicellular organisms may reproduce by freeing, through division, single-celled offspring, which are, of course, the immediate product of cell and nuclear divisions taking place in a certain line of cells in the body of the multicellular parent. These divisions are homologous with the reproduction described in (a) in that these reproductive cells are formed by nuclear and cell division. The process differs from (a) only in the fact that the dividing cells that form the offspring are harbored in a many-celled body. We may say then that reproduction in (a), with its double aspect of cell division and bodily division in one operation, has become specialized in (b) into two separate possible operations, one of the multicellular body and the other of the unicellular germ cells, contained in that body.

3. *The Ratio in Size of the Parental Body to That of the Offspring.* In its simplest form the division of the parent, whether one or many-celled, into new individuals may be considered as producing two practically equivalent offspring, each of which has one-half the endowment of original parental material. So far as this ratio is concerned the condition is much the same in the unicellular organisms and in those multicellular ones,—as flatworms, naidiform oligochetes, and the like,—in which there is division into essentially equivalent daughters. In both cases we may fairly say that the parental organism is completely destroyed in the act of reproduction. Strictly speaking, there is no parent left, and the two offspring formed are mutually at the highest advantage possible to offspring in that they only have to double their material to be at complete maturity of individuality. (See third column of chart.)

4. *Depreciation in the Volume of the Reproductive Units (Offspring).* The method just described is at a maximum of sacrifice on the part of the parent with maximum biological advan-

tage to a limited number of offspring. It leads to well endowed offspring, brief periods of immaturity, numerous reproductions, and impermanent individuality on the part of the parent. From this simple condition as a starting point there are, in practice, two departures found in organisms whereby a certain form of increase of effectiveness is obtained: (1) there may be a division of the entire parent into many offspring, by fragmentation, sporulation, etc., which continues the complete destruction of the parent as in the former case, but reduces the endowment of each offspring. The compensating fact is the increased number of offspring. This device increases the period of immaturity and in consequence pushes apart the successive reproductive generations; (2) the second case is illustrated by a budding process such as is seen in the yeast cell or in hydra,—or by the condition to be described later for still higher forms. In these the parent is not completely destroyed, and the one or many offspring are reduced correspondingly in volume and in initial vital efficiency. This diminution in volume may be such that the offspring of a multicellular organism may consist of a single cell. This is clearly a much more economical mode of reproduction with very much less drain on the parent; it allows a more continuous parental existence with an increased emphasis on permanency of individuality; it makes possible frequent or even continuous reproductive activity, with more numerous offspring.

5. *Depreciation in Value Accompanying Depreciation in Volume.* It will be realized in connection with the above that the economy and gain through safeguarding the parent and in the capability of producing many offspring has been purchased at the expense of the amount of the original parental material going to each offspring. As the result of this reduction in volume the offspring necessarily has a longer, more difficult course to run in coming to reproductive maturity. This means that the decreased volume entails a decreased present biological value in the reproductive units. The more the offspring differs from the parent the more extended and difficult is its task in reaching maturity. The reduction in volume and in value is greatest in our higher, more complex multicellular animals and plants in whose case the new offspring is merely a single cell at the outset. This condition is il-

lustrated both by the spores and gametes. In the gametes, which are reproductive units that normally unite before development, and in the spores, at least of the higher plants, there is another most interesting reduction to which further reference is made in Section 9. Here the offspring is not merely reduced to one cell; the number of chromosomes in the nucleus of that cell is reduced to one-half the number characteristic of the individual body cells of the species. One further step in the depreciation in volume is seen in the sperm (or male) cells in most animals and plants. In addition to the loss of one-half its chromosomes, the male cell is much reduced in the amount of cytoplasm.

6. *The Necessity of Restoration.* The depreciation of the one-celled offspring of the higher animals and plants described in the preceding section is shown further by the fact that these new offspring are frequently unable to enter, as soon as they are formed, upon the series of cell divisions and other changes which have been described as necessary to maturity. Their further development seems to be checked in part by the excessive reduction they have suffered. This is very often true of spores, which may not undertake to germinate for some time after their formation, even though external conditions seem favorable. The gametes, eggs and sperm, are normally even more incapable of entering at once on the stages that lead to maturity, without external help. It is even more true of the sperm than of the egg. The sperm, it will be recalled, is like the egg in having only one-half endowment of chromosomes; it has also lost the major part of its protoplasm, of which the egg has an abundance. The spores and the eggs of many species may develop rather promptly, but so far as we know the sperm is so reduced in the typical higher plants and animals as to be wholly incapable, in itsef, of developing into the adult. (See column six of chart.)

It would seem, therefore, that the tendency to economize parental expenditure and to increase the number of offspring had overreached its mark,—defeating in large degree its prime result of economic reproduction. At this point in nature we find a series of recuperative processes by which these reduced reproductive bodies are given the power to resume their activities and are restored ap-

parently to a vigor which enables the single cell to develop, in proper order, all the essential characteristics of the species to which it belongs. Because of these restorative processes these single-celled reproductive units cease to be merely single cells; they are potential adults.

7. *Methods of Restoration.* This need of restoration, suggested by the great reduction in the parental substance—the cytoplasm and chromatin—that goes to each of the unicellular offspring and reinforced by the fact that they are often unable at once to develop, is met in nature in two or three principal ways.

In the first place, and most simply, it frequently happens that the offspring may regain this power of developing to the mature state by a mere season of rest or quiescence, without any other change of condition. This is quite commonly true of the spores. It is not always true that the spores need such a rest period, however; they may often develop directly. (See column seven of chart.)

Secondly, in addition to the mere lapse of time the spores, after leaving the parental tissues, are undoubtedly subjected to decided changes in respect to moisture, temperature, and other important environmental conditions. These changes may themselves, rather than the mere rest, be the stimulating and restoring agency. We know that decided changes in environmental conditions do stimulate renewed activity in vital processes. This may be analogous to the artificial stimuli that arouse unfertilized eggs into action as described below.

In the third place, the gametes usually demand more than rest. In this type of reproductive units, where chromosome reduction is well nigh universal, it is ordinarily essential that two gametes (offspring)—each containing one-half the specific number of chromosomes—shall unite and bring the contents of both the cells into one. Such a united cell, which is no longer a single reproductive body or offspring, but rather a fusion of two offspring, has the power of development, which did not reside in either of the original cells. This is called conjugation or fertilization. It frequently happens that a period of rest is also needed in connection with these unions, though this is not the rule.

Finally, it has been discovered by experiments that this restoration and immediate power of development of gametes (the egg particularly) can be secured in some organisms in various artificial ways. These consist for the most part in applying to the gametes certain conditions,—changed mechanically or chemically from the normal. This is known as artificial *parthenogenesis,*—and means that certain eggs which would not ordinarily begin development without union with another cell may be caused to develop by chemical and mechanical stimuli. It will be seen that this is analogous to the condition described in the second type of restoration above, by which spores may come to the point of developing through changed external conditions. The same power is sometimes normally possessed by the larger of the two gametes,—the ovum (parthenogeneses: section 9).

8. *Conjugation (Isogamy).* In that form of restoration of power to the offspring, in which gametes unite and, by fusing two half-sets of chromosomes, regain the full complement of chromosomes, the most simple form has uniting gametes in which no difference is distinguishable. So far as we can see, each of the offspring entering into the fusion is exactly equivalent to the other. Each has suffered equal reduction as compared with the original parent, both in protoplasmic substance and in chromosomes. We cannot properly use here the terms male and female, nor fertilization, nor sex. The fusion is mutual and there seems no differentiation of function in the gametes. This is known as *isogamy* or *conjugation.* In some cases the conjugation is *facultative;* that is, the gametes usually conjugate, but if this does not occur, they may after a period of rest develop without it.

9. *Differentiation Among the Gametic Offspring (Heterogamy).* In many species of organisms the same individual may produce two different kinds of offspring or gametes. In such cases the gametes may be nearly alike, differing only slightly in size. In other species there may be great difference in size and behavior. At the extreme of this differentiation we have the two types of offspring known as *ova* and *sperms.* Characteristically, the eggs are unicellular offspring, which are large, spherical, well nourished, and sluggish cells, with much protoplasm, but only one-half the specific

number of chromosomes at maturity. The sperms, on the other hand, are usually actively motile cells, of very various shape, though not spherical like the egg. They are much reduced in protoplasm, but they have the same number of chromosomes as the ova,—that is, one-half the specific number. (See column four of chart).

This condition introduces *sex*. The ova are known as *female* and the sperm as *male*. The union of the ova and sperm, in pairs, which is usually necessary to restore the power of development, is called *fertilization*. In some species the ova may develop without union with the male cell. This is known as *parthenogenesis,* and it is possible that this ability represents the action of some condition of the parental body, analogous to hormone action, which substitutes some other stimulant for that of the male cell, which is the usual or normal one.

It is necessary to insist that the eggs and the sperm are the real *offspring,* and that the act of reproduction in the female is the production of eggs; that reproduction in the male is formation of sperm; and that fertilization, which is union, is not reproduction at all, but the direct opposite of it. It is in part at least a restorative process following upon the reduction and depreciation of the gametes in reproduction, and instituting a series of cell divisions which provides both for the new parental body and the new generation of reproductive cells (offspring) which are derived from it.

10. *Differentiation of Organs of Sex.* In the simplest state of the formation of the reproductive units, especially before these units themselves are sharply different, the organs or structures in plants and animals which produce the two kinds of offspring are not only in the same individual *(hermaphroditism),* but they are much alike, except for the fact that the gametes they produce differ more or less. There is, however, a perfectly clear tendency for the organs and structures connected with the production and distribution of eggs (female offspring) and the sperm (male offspring) to become different,—and often very markedly different, even when they occur in the same individual,—quite as diverse indeed as are the offspring which they produce. This is a quite common kind of hermaphroditism, in which a single plant or animal develops two dif-

ferent, and often very complex, sets of sex structures to produce and take care of the two kinds of offspring so as to insure their fertilization and development. It is illustrated in earthworms, snails, and many other organisms. Ordinarily this union is supposed to be not between the offspring of the same parent, but of different parents *(cross-fertilization)*. Doubtless self-fertilization is also frequent.

11. *Diversification of Parents (Sex-dimorphism)*. The problem and function of producing and caring for ova is so different from that of producing and caring for sperm that such a differentiation as we have seen in the last section takes places in the organs that do the work. This differentiation does not in the majority of animals and plants stop here. The differentiation of sex, first seen in the offspring (eggs and sperm) and then in the organs producing them (ovaries and spermaries), comes to show in the individuals which bear the organs; and male individuals come to be differentiated from female individuals as much as ovaries differ from testes or ova from sperm. (See column five of chart).

Among animals and plants can be found all degrees of these sex differences. We have individuals that produce ova and have female organs and characteristics at one period of life, and later are males and produce sperm. In others, permanently male or female, the external differences are so slight that dissection of the organs of reproduction alone can determine the sex of the parent. In still others there are such striking differences between the sexes that they would not be regarded as belonging to the same species of organisms from structure alone. This is the condition in most of the higher organisms, and is particularly striking in all the higher animals. The differences between the male and female in man, in birds, in many insects and spiders are matters of common observation.

12. *Parental Care of Offspring.* The depreciation of offspring in the interest of economy to the parent and of increased number of offspring, coupled with the resulting need of restoration by fertilization or some other device, has led to other most important biological results. The longer course over which the offspring must go to reach maturity, the diversification of the gametes, and the con-

sequent diversification of the male and female parents furnish the biological groundwork for very interesting adaptations for mating, home-making, parental care. These adaptations may be structural, instinctive, emotional, or intellectual. These are among the highest and most stimulative of the biological phenomena,—upon both parents and offspring. Because of such conditions the care-taking, sympathetic, social aspects of parents are emphasized, the period of filial dependence is made longer and more fruitful through association with parents, and the motives for social life and development are introduced. It is not easy for the student to exaggerate the evolutionary importance of this group of phenomena correlated with reproduction, and common in many animals of the higher groups.

13. *Combination of the Reproductive Methods in One Individual.* In what has been said the process has been treated as though a given species of organisms had only one mode of reproducing. As a matter of fact we often find that a plant or animal will for a period show some form of mass division (vegetative reproduction)

EXPLANATION OF PLATE VI

The scheme represents an effort to put in tabular form some of the more important relations suggested in the discussion. The vertical columns indicate certain of the classes of facts connected with reproduction. The horizontal subdivisions express some of the important variations in respect to the particular phenomena named at the head of the columns. In a general way the category nearer the bottom of the page at each step is looked upon as the lower, and as giving rise to that above it. For example, the following free translation will illustrate what is conceived as the simplest condition from which others have arisen: "Direct mass-division of unicellular parents into (2) offspring, equal to one-half the parent and equal to each other, which demand no special restoration to enable them to begin the new growth, is exemplified by fission among the Bacteria." The signs + and — in column six indicate "requiring" and "not requiring" restoration respectively.

It is not intended always to imply that the subdivisions in a brace are strictly logical subdivisions of the category preceding. For example: "Many O." near the bottom of the fourth column manifestly cannot be a subdivision of "O = ½ parent"; it is rather thought of as a derivative and extension of the fission process, whereby "2 equal O." are produced from the one-celled parent.

-and ATION of	METHOD:- 1. REST 2. UNION	TYPE OF REPRODUCTION
on	UNION	Dimorphic Sexuality.
on		Parthenogenesis- BEES. APHIDS.
on	UNION	Hermaphrodite E.WORMS
tion		Spore Formation
n	REST	Tubers
on		Budding; E.G. HYDROZOA.
n		Flat Worms (FISSION)
on	UNION	Eudorina.
on	UNION	Vorticella.
on	UNION	Some Heliozoa
	REST	Golpoda. Ephelota.
on		Yeast etc. Budding
on	UNION	Plasmodium.
on	UNION { of TWO	Chlamydomonas THE SMALL ZOOSPORES
	of MANY	Actinospherium MYXOMYCETES
	REST	Scenedesmus ACTINOSPHERIUM
tion		Yeast:- ASCOSPORES
n	UNION { PERM'T	Desmids
	TEMP'Y	Paramecium
	REST	Euglena
n		Bacteria (FISSION)

Essence of Reproduction	a. Cellular / b. Bodily (individual)	Ratio between Parents and Offspring	Diversification of the Reproductive Units	Diversity of Parents	Loss of Power and Need of Restoration in Offspring	Method: 1. Rest 2. Union	Type of Reproduction
Direct Mass-Division of Parents	Multicellular Bodies	(Depreciation) Parents much larger than Offspring	O. {Unicellular / Unequal} from	2 diverse parents	+Restoration	Union	Dimorphic Sexuality.
					−Restoration		Parthenogenesis—Bees. Aphids.
				1 Parent	+Restoration	Union	Hermaphrodite E. Worms
			O. {Unicellular / Equal}	1 Parent	+or−Restoration		Spore Formation
			O. {Multicellular / Equal (or unequal)} 1-Many		+Restoration	Rest	Tubers
					−Restoration		Budding; E.G. Hydrozoa.
		O. = ½ Parent	O. Equal : 2		−Restoration		Flat Worms (Fission)
	Unicellular Bodies	Parents much larger than Offspring	Two or More O. — O. Unequal	Dif. parents but similar	+Restoration	Union	Eudorina.
				Same parent	+Restoration	Union	Vorticella.
			O. Equal		+Restoration	Union	Some Heliozoa
						Rest	Colpoda. Ephelota.
					−Restoration		Yeast etc. Budding
		O. = ½ Parent	Many O. — Unequal		+Restoration	Union	Plasmodium.
			Many O. — Equal (Sporulation)		+Restoration	Union {of two / of many}	Chlamydomonas (the small zoospores) / Actinospherium (Myxomycetes)
						Rest	Scenedesmus (Actinospherium)
					+or−Restoration		Yeast:- (Ascospores)
			2 Equal O. (Fission)		+Restoration	Union {Perm't / Temp'y}	Desmids / Paramecium
						Rest	Euglena
					−Restoration		Bacteria (Fission)

or spore formation, and will then, owing to some change of conditions internal or external, enter upon reproduction by gametes. The same individual, thus, at different periods of life or with different stimuli in the way of temperature or nutrition and the like, may combine the advantages outlined in the preceding sections in the various special methods of securing the reproductive act. The possession of these several methods of reproducing of course makes possible a much more equable and adequate response to the varying environmental pressure.

14. *Alternation of Generation,—a Combination of Reproductive Methods in Different Individuals Constituting a Single Life-Cycle.* Another form of combination of reproductive methods than that described in section 13 is found in most of the complex plants and in many types of animals. It consists essentially in, we may say, a reproduction by gametes, in which the egg is fertilized by the sperm in the usual way resulting in a type of individual which we shall call "A"; individuals of the type "A" become mature and do not have the power to produce gametes at all, but, on the contrary, they may bud, or divide vegetatively, or form spores; when these new individuals come to their reproductive maturity they are different, often very different, in appearance from individuals "A", and may be called "B". This second type of organisms in its turn cannot reproduce as "A" reproduced, but reproduces by gametes, and the embryo resulting from their union matures into a type like the original "A". We have thus come round to the same point in the "cycle" at which we started, and in doing so we have had two succeeding types of individuals in the same species and two different methods of reproduction regularly alternating. "A" produces non-sexually individuals "B", and "B" reproduces sexually individuals "A". In coelenterates "A" is the tubular type, multiplies by budding and ultimately produces the medusoid individuals "B". These latter reproduce by eggs and sperm, from the union of which the tubular hydroid forms are again produced.

In plants, "A" is known as the *sporophyte generation,* which produces spores. When the spores germinate they produce the new and very different *gametophyte generation,* which reproduces by the

formation of gametes, male and female. The union of these initiates the sporophyte generation again. (See text Fig. 1.)

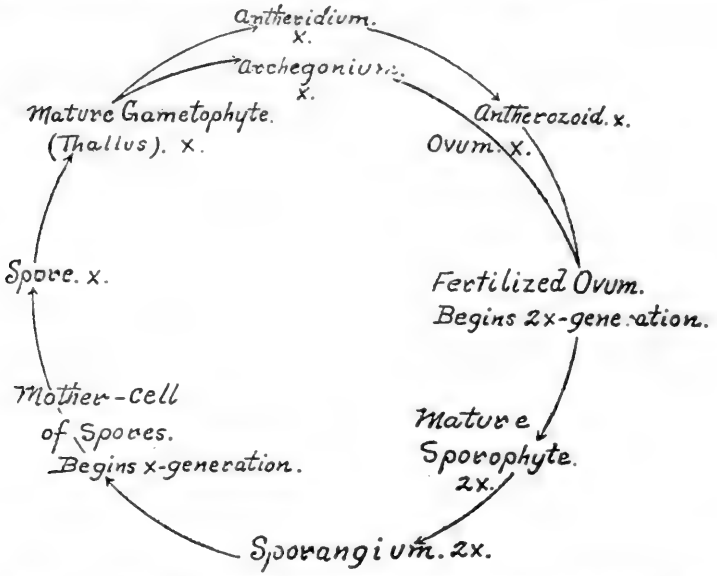


Fig. 1.—A diagram to illustrate the life-cycle, the alternation of generation including the relation of the x and 2x condition of the chromosomes, in one of the higher plants (e. g. a fern). The fertilized ovum is the beginning of the sporophyte generation. The spore is the beginning of the gametophyte generation.

15. *Relation of the Chromosome Reduction to the Alternation of Generation.* The two kinds of gametes possess a number of chromosomes characteristic of the species. This number is spoken of as x. When they unite the chromosomes of male and female gametes do not lose their integrity, but the resulting embryo has the double number of chromosomes, or 2x. As cell division occurs and the resulting plant becomes multicellular, the number of chromosomes is not reduced, but all the body cells of the new plant (sporophyte) have 2x chromosomes. This remains true until the nuclear divisions immediately preceding the formation of the spores, or non-sexual reproductive bodies. At this time there is a reduction to one-half the number, and thus the spores themselves contain nuclei with only the x number of chromosomes.

As the spore germinates and the new multicellular generation (gametophyte) is produced this condition is unchanged; and since the gametes are formed from the gametophyte they have likewise the x chromosomes, as we saw at the beginning of this section. In the union of the gametes the double number is again restored.

The condition is pictured in the accompanying diagram (Fig. 1). The relative length and importance of these two generations is very varied in the different groups of plants, but the alternation of generation, and the distinctive reduction and restoration of chromosomes by which the generations are marked are very constant.

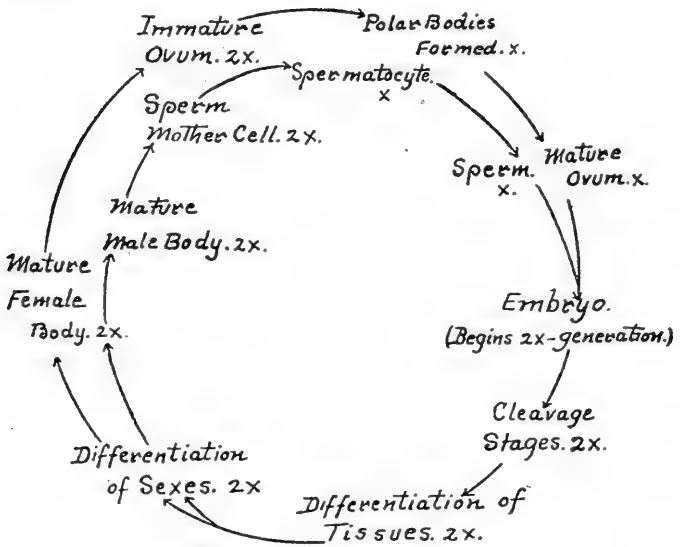


Fig. 2.—A diagram to illustrate the life-cycle and the x and 2x state of the chromosomes in higher animals. It will be seen that the x stage is very brief.

A condition somewhat analogous is seen in diagram, Fig. 2, which represents the condition in higher animals. Whether it is more than analogy we are not now prepared to say. The ordinary body of the animal is made up of cells with 2x chromosomes. This continues up to the time of the formation of the gametes. In their formation and maturation the number is normally reduced to x, immediately to be doubled upon the union of the gametes in fer-

tilization. This reduction and doubling of the chromosomes is strongly believed to be closely connected with the hereditary transmission of characteristics from two parents, and seems to have to do with the changes in the germ plasm that produces variation within the offspring of the same pair of parents.

T. W. Galloway.

The Growth of a Compound Eye

As is well known to students of insect life, there is a period between the larval and adult stages of development when important structural changes take place. For instance, take one particular type of organ, such as the eye. In a moth larva such as the Tussock, *Notolophus leucostigma,* the larva has several single eyes grouped on each side of the head. Somewhere between the time of its entering upon the pupal stage and its emergence therefrom as an adult it exchanges these simple larval eyes for an elaborate pair of compound eyes. How it does this, and what becomes of the old larval eyes, is a process so well hidden from view in the pupal case that only cytological work can reveal the secrets.

When ready to pupate the larvae of most moths seek various sheltered positions in which they undergo their final molt or shedding of the larval cuticula. This leaves the hypodermal (epidermal) cells of the creature raw, under which conditions they exude a fluid which hardens and forms the pupal case.

As most individuals of a brood undergo their stages at similar intervals one may by collecting a number of pupae at this stage get material for studying not only the stages of the eye, but of other structures as well. By selecting individuals, at say two-day intervals from the first day of pupation onward, we will get a series showing the progressive development of the parts.

The pupa so selected should be opened in the back by a sharp instrument to allow the rapid penetration of the killing and fixative fluids. If any particular part of the tissue is wanted, it is necessary to be very careful, in making openings, not to injure or deform the tissues in the immediate vicinity.

During the pupal life, two very important and entirely opposite processes are necessarily very active. One is the breaking

down and absorption of the useless larval structures. This destructive process is carried on by two different factors:—by phagocytes, a special form of cell which gives out certain products which break down and disintegrate passive adult cells into blood pabulum; and by natural breaking down processes of cells which have lost their functional places in the changing economy. The other or opposing process is one of rapid cell division and growth of new types of cells which are to become differentiated into new adult organs.

In the first class of structures which disintegrate, we may include the larval types of eyes. These, following all the previous larval molts, have grown a new cuticula and have retained their function; but now it is no longer so. With this last molting process they immediately collapse and shrink toward the brain to which they are attached. Here they will be recognized in the photos of subsequent stages as the dark pigmented masses at the posterior lobe of the brain. Finally through growth of the brain they come to lie well down on the stalk of the lobes.

Let us now turn toward another aspect of the head of the creature. During larval life the cheeks of the larva were plump with masses of muscle which were absolutely essential in working the cutting jaws during the active voracious life of the caterpillar. From now on these muscles are useless, as the biting jaws will never be used again. These rounded cheeks are destined to become the seat of a new activity; they are to become the site of the enormous compound eyes of the adult insect, containing many hundreds or thousands of eyes, as the case may be. The phagocytes have been active for several days and there is a large cavity filled with body fluid in each cheek. This blood fluid contains numerous phagocytes, many broken down tissues, and many fat cells which enter through the wide neck opening from the thorax. In the meantime, the ectodermal layer of cells has proliferated to quite an extent so that there is a seemingly chaotic mass several cells deep.

Fig. 1 (Plate VII) represents a frontal section of the head in the region described above, passing through both brain lobes and through the regions to be occupied by the compound eyes. The

larva is in about a four-day stage of pupation. This photograph may serve as a topographic chart to which may be referred all the special organs mentioned in later figures.

Fig. 2 is an enlarged view of the optical elements of the same 4-day stage. Practically all the cells which are to form the future eye tissue are now present and there is to be no increase in number henceforth. Later change is due to growth and differentiation of these cells. That is, the cytoplasmic vegetative systems of these cells are to grow into their hereditary forms, and the individual cells are to adjust themselves into their peculiar group relations. What looks at this stage as a hopeless jumble of cells without order or form, is the foundation of an order which will develop itself with remarkable speed.

If we now turn to the next or 5-day stage, shown in Fig. 3, we shall see that the cells have undergone a remarkable arrangement into definite groups, each of which is an exact duplicate of its neighbor. Also within these groups, they are beginning to show definite shapes and relations to each other. Their vegetative systems also grow to show more of their future structural characters. Order has appeared out of seeming chaos.

By examination of the 6-day stage, Fig. 4, we will see that the mass of optical elements has doubled in thickness by the growth of the cell systems.

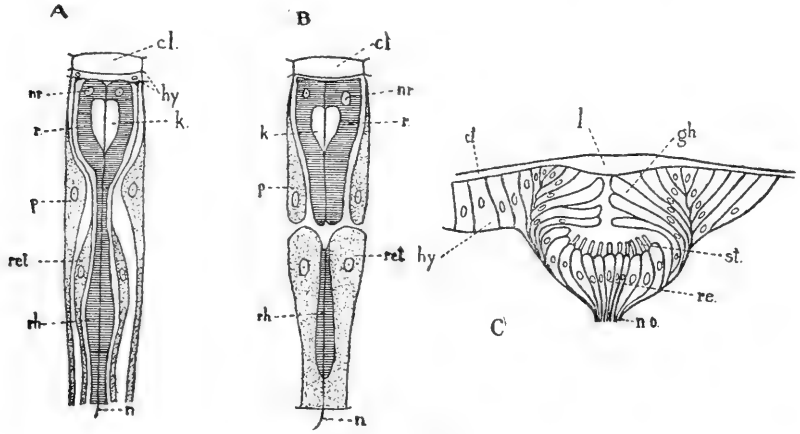
Fig. 5 is a view of the optic lobe of the brain at this same 6-day stage. There has grown a bewildering complexity of elements here. The large dark pigmented mass is the rudiment of the larval eyes.

We will now turn to the 8-day stage well shown in Fig. 6. Here we find the cells again doubled in bulk as compared with the 6-day stage. The pigment cells and nerve cells are greatly elongated and now reach backward nearly to the brain itself.

A cross section of these groups of optical elements is shown in Fig. 7 (Plate VIII). Here the elements are seen to be grouped into hexagons, an effect produced by pressure of the opposing groups of cells. Toward the margin of the section the elements are, of course, cut obliquely. A surface view of the cornea, as

Fig. 8, shows the beautiful regularity of the hexagonal visual elements.

As to the cytological structure of these compound eyes, there are several views. Two of these taken from Lang's "Comparative Anatomy," pages 470 to 471, are here illustrated in diagrams (text figures) A and B. These authors both consider the hypodermal layer of cells as distinctly a layer by itself. We can hardly agree with this view, however. In all the types of eyes examined we find that in the early stages there is but a single layer of cells in the hypodermis. Later some of the cells draw inward and by division give rise to other cells which form the ommatidium group. So it appears to us that the whole group of cells is strictly hypodermal in origin. These cells now elongate, forming spindle shaped cells which extend more or less the entire depth of the ommatidium. Such elongated undifferentiated cells are seen in the eye of the



The structure of an ommatidium (single eye) of the compound eye:—A, according to Patten's view; B, according to Grenacher's view. *cl*, cuticular corneal lens; *hy*, hypodermis cells; *r*, retinophorae-crystal cells; *nr*, nuclei of the same; *k*, crystalline cone; *p*, pigment cells; *ret*, retinulae; *rh*, rhabdome; *n*, nerve.

According to Patten (A) the ommatidium is apart from the corneal hypodermis, of one layer, all its elements passing by means of thin processes through its whole thickness from the base of the corneal lens; according to Grenacher the ommatidium, apart from the corneal lens, consists of two layers. (Taken from Lang's Comparative Anatomy, page 471.)

C, Section through the ocellus of a young Dytiscus larva (after Grenacher.): *ct*, chitenous cuticle; *l*, cuticular lens; *gh*, cells of the vitreous body; *hy*, hypodermis; *st*, rods; *re*, retinal cells; *no*, optic nerve.

male Ephemera, Fig. 9, (1). The nuclei of these cells gradually migrate as they grow to the localities where they are found in the adult eye.

The corneal hypodermis consists of a varying number of cells arranged in hexagons following the shape of the compressed ommatidium below. When the crystal cells begin their enlargement these corneal cells are displaced by their outward growth and finally come to lie around the base of the cone group of cells. This is well shown in Fig. 9, (2) of the Ephemera eye. They are thus seen to be the last of the hypodermal cells to assume the elongated spindle shape lying vertical with the rest of the ommatidium group. See also Fig. 10. So we consider there is really but one layer in the eye when they have all reached adult stages. In both the diagrams the rhabdome should have been shown as a nucleated cell, being the central cell of the group of retinular cells. The nucleus of the rhabdome cell finally comes to lie at the inner margin of the eye. We believe, therefore, that the usual method of diagramming of the optic nerve is wrong, the central retinular cell

DESCRIPTION OF FIGURES

PLATE VII

Fig. 1. Tussock Moth, 4-day pupal stage. Frontal section thru brain and compound eye.

Fig. 2. Tussock Moth, same stage. Portion of developing eye much enlarged.

Fig. 3. Same, 5-day pupal stage. Region similar to Fig. 2.

Fig. 4. Same, 6-day pupal stage. Similar region.

Fig. 5. Same, 6-day pupal stage. Optic lobe of brain.

Fig. 6. Same, 8-day pupal stage. Region similar to that of Figs. 2-4.

PLATE VIII

Fig. 7. Tussock Moth. Eye elements cut in cross section.

Fig. 8. The corneal lenses of the compound eyes of *Tabanus astrata.*

Fig. 9. Eye of male Ephemerid: 1, spindle cells; 2, hypodermal cells; 3, rhabdome cell.

Fig. 10. Eye of a female *Rhamphomyia*—a Dipteran.

FIG. 1

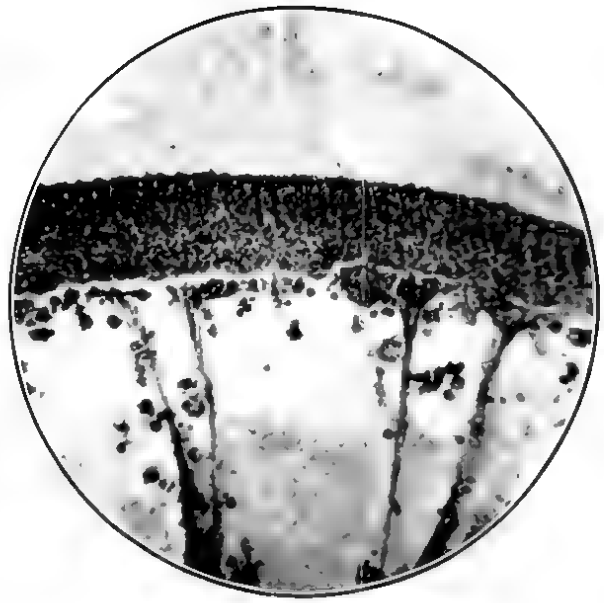


FIG. 2

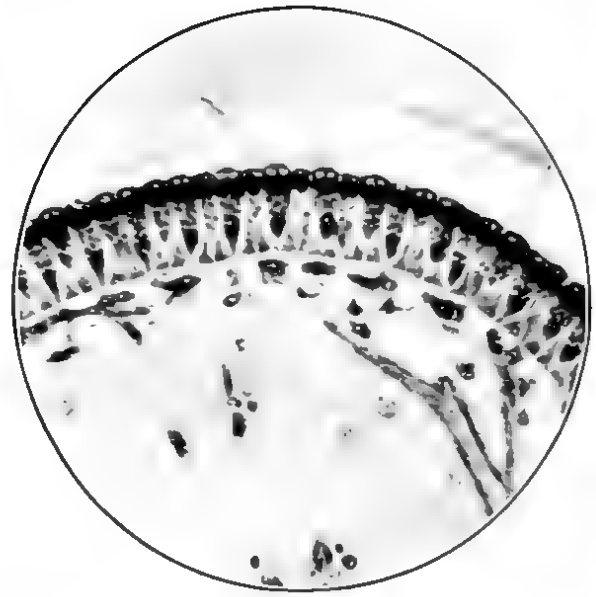


FIG. 3

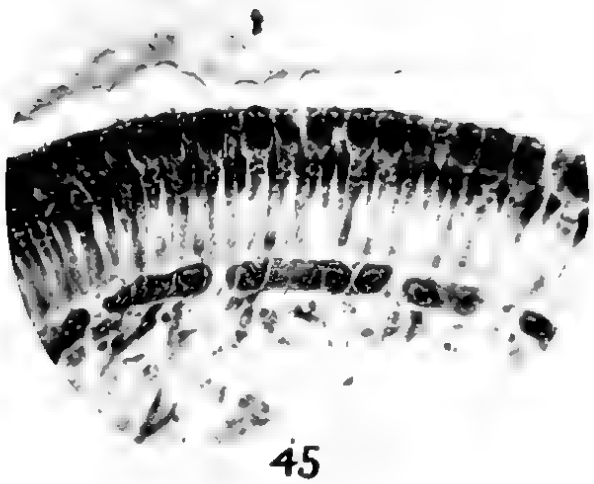


FIG. 4

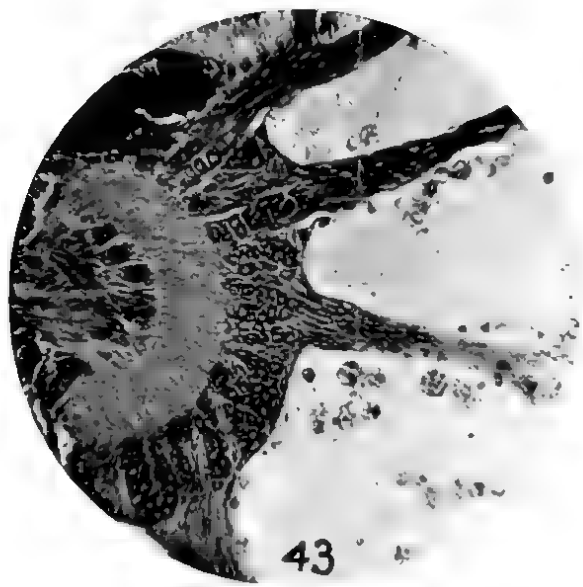


FIG. 5

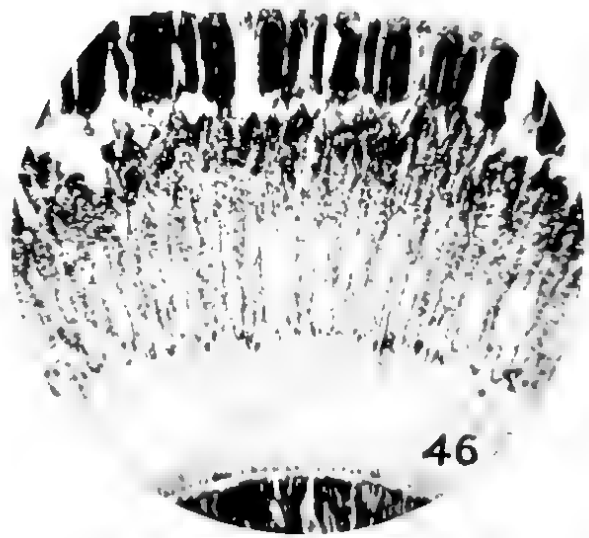


FIG. 6

PLATE VII

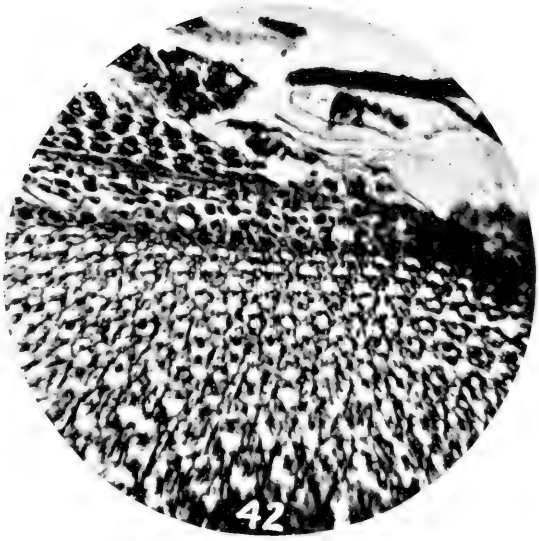


FIG. 7

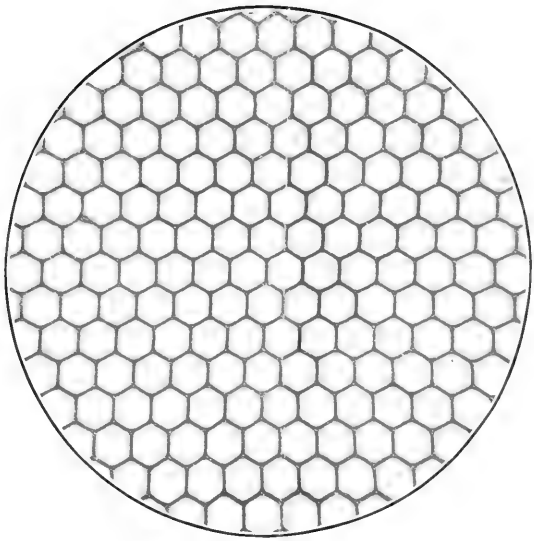


FIG. 8

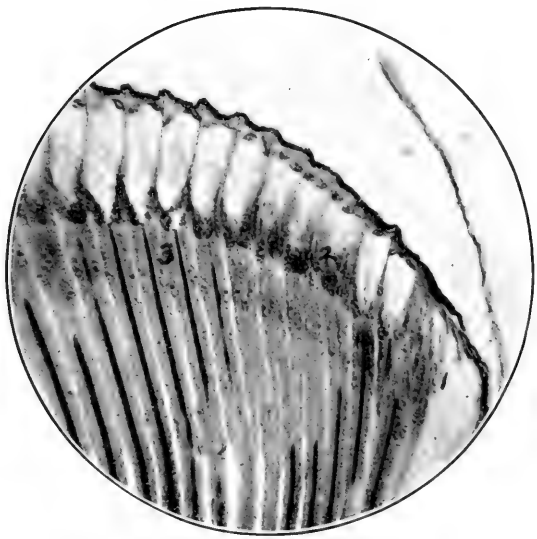


FIG. 9

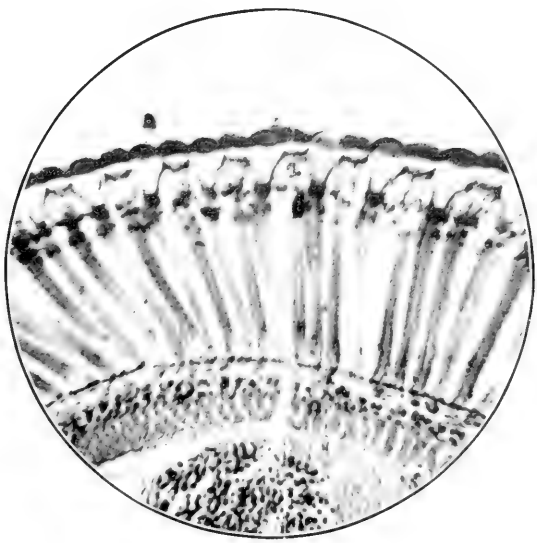


FIG. 10

PLATE VIII

being the nerve cell, which extends outward among the crystal cells and inward where it connected with the ganglion cells of the brain, as seen in the Tussock photos.

The compound type of eye is generally considered to be an elaboration of the ocellus or single eye type of larval forms. If we compare the diagrams of the ommatidium by Patten and Grenacher with the ocellus of a larval form (see text Fig. C, after Grenacher) we can see the probable homology of the various cell structures. We may consider the rods (st) on the retinal cells (re) as the remains of spines on the hypodermal cells which form the optic invagination. This same spine structure also forms the olfactory nerve endings on the antennae of the Diptera. In the ommatidium of the compound eye, of the seven retinular cells, all but the central one has lost its rod. This rod we consider to terminate at the base of the crystal cells as seen in the Ephemera material. This termination corresponds with the position of the rods in the ocellus. See Fig. 9 (3).

The cells which close in from the sides in both the ocellus and ommatidium forming the crystal cells may be considered as homologous. They may be considered as full length cells much compressed in a lateral direction.

The space in which the crystal cones of the ommatidium are deposited is homologous with the space between the rods and the vitreous body cells of the ocellus type.

These observations do not lead us to believe that the ideas of either Patten or Grenacher are entirely correct in regard to the structure of ommatidium.

E. W. Roberts.

Battle Creek, Mich.

FRESHWATER HYDROIDS

The now familiar Hydra seems to have been first noticed in the year 1703. About 40 years later the observations or experiments of Abraham Trembly of Geneva excited a widely extended interest in it, not so much because of the peculiarities of its life history, as from its apparent indifference to the many seemingly fatal wounds given it to produce its death. On account of the interest taken in these experiments, this creature was often referred to as the Zoophyte of Trembly, but this had long since lapsed into the common, as well as generic, name of Hydra. Three species are generally recognized in this genus, as *Hydra vulgaris, Hydra viridis,* and *Hydra fusca,* on account of a variation in the number of their tentacles, a difference in their color, or an increase in their extensibility and consequent contractility. This is most conspicuous in the case of *Hydra fusca,* where we may first see it after disturbance as a "ball of greenish jelly," lengthening a moment later into a slender thread or stem, from near the distal, or outer, end of which six or more tentacles are budded out rapidly, lengthening into a drooping mass or fringe of extremely delicate filaments knotted along their whole length with what are known as lasso, or poison, cells. The water-flea or other Protozoan which accidentally touches one or more of these, is liable to be paralyzed by some of these poisonous darts, when the fortunate tentacle shrinks down to the mouth of the Hydra, quickly opened to receive it, and—*"facilis decensus averni."* So much for the common Hydra, which will easily be recognized.

The next Hydroid to join the list of freshwater forms was *Cordylophora lacustris,* much more complicated in its structure, wherein it nearly resembles several of the marine forms, and, while it does not throw off any free-swimming medusæ, it does, at certain seasons of the year, give birth to so-called *hydranths* that take root and grow up directly into a new generation of hydroids.

Following this come the Medusae, *Limnocodium sowerbii* and *Limnocnida tanganyikæ,* found respectively, the first in Regents Park Gardens in London in 1880, the other in 1883 in Lake Tanganyika, Central Africa. The parent hydroid of neither of these, or from which presumptively it must have arisen, has not,

as yet, been positively ascertained, although Mr. Bourne and others did find in other tanks and in the Kew Gardens, also in London, a hydroid greatly resembling the next to be described form, from which they assumed it may have descended. This connection the writer thinks has not, for reasons that will be given, been fully proved.

In the spring of 1885 the writer of the present paper, while studying the life history of a new Polyzoan, which he had named *Paludicella erecta,* found upon the surface of some stones collected during the previous autumn in the neighborhood of Philadelphia, Pa., and kept over winter in his home, some novel forms that he soon convinced himself were of hydroid character, though entirely destitute of tentacles, or of other organs of prehension or locomotion. These, with the consent of his friend, Dr. John A. Ryder, of the University of Pennsylvania, form the new genus *Microhydra ryderii.* They are about one-half a millimeter in length when single, or when branching near the base, which will be called the *pedal disc,* the total length is about one millimeter from head to head. The diameter of the cylindrical body is about one-tenth millimeter. A few lasso cells are scattered along it, but a great many, say 40 or 50, are collected upon each capitulum or head. Here the mouth is placed, but, except when the lips are everted while feeding, it is with difficulty recognized. As no means have yet been discovered by which it may remove or re-attach itself upon its pedal disc after removal, and having no grasping organs, our perplexity may be easily pardoned, when we strive to understand how this animal can catch others of better motive powers, and feed itself by killing them when caught. Many observations looking toward a determination of that point are narrated in a paper entitled *"Microhydra during* 1907" and published in the Proceedings of the Delaware Co. Institute of Science, Vol. III, No. 3, issued May 15, 1908. The space allotted me in the present publication will not allow of many of these, except to say that, lying as it were *perdue* upon the surface of these stones, under the protection of a crowded growth of Polyzoa and other localized animals, they are very likely to be crawled over by small annelids,

and many Protozoa still smaller, whom they can paralyze with their darts, and twist their mouths around so as to secure.

Although a stock of these interesting creatures was rarely, perhaps never, absent from the jars upon my study table, it will be noticed that it was not until 1897, or twelve years after their first discovery, that medusa buds were seen to be formed upon the hydroid stems, a millimeter in length, nor was an opportunity found until a lapse of ten years more for a more particular study, as will be presently described.

To supplement this, which is known as the sexual process of its development, nature, or, more properly its Author, has provided another, an a-sexual method of reproduction that deserves to be at least briefly described:

We may see quite frequently, but better when Microhydra is located upon the edge of a stone and stretches out so as to be brought into clear view by transmitted light, depressions at both ends of the *middle-third* of one side of its body. That, at the distal end, deepens more rapidly than the other, and, by a novel method of longitudinal fission, gradually approaches the other, the cellular structures of both parent and larva healing up and rounding out as the separation progresses. Finally the larva is nearly liberated and hangs by an invisible thread, until in our jars it is by any motion of the water wafted against the glass, where it temporarily adheres, an organism without organs, no capitulum, no pedal disc, no apparent mouth, no means of catching prey, or feeding upon it when caught. Plainly it is an inert, helpless body that we may safely call a larva, until we find, a week or ten days later, that a capitulum has been formed, a pedal disc prepared upon which it now stands upon the surface on which it may have been lying, and is now prepared to sustain life on its own account. I have watched this whole operation perhaps a score of times, and have found the process of segmentation to take about eight hours. I have said that during the larval period it is without organs of locomotion, yet we have been always ready to admit that it *does* move, probably by some amæboid action of its surface cells, that my eyes have not been quick enough to catch, even with the microscope.

It is recognized that any suggestions to students to collect and study this interesting group must be ineffective if they do not include information from my experience as to their favorite living places. Tacony Creek, although it furnished the first specimen, is not ideal, while Flat Rock Dam certainly is such. Most successful collectors of the plant-like fauna of our fresh waters early learn that these prefer to grow where rapid currents bring them a constant supply of food, and, at the same time, prevent silt from gathering over and smothering them. The factories along the Schuylkill Canal require much more water than is furnished by the infrequent opening of the canal gates to let boats through. For this reason a number of tunnels have been built to pass water from above the dam into the canal below the first set of gates, and at the point where they enter, at a depth of 6 or 8 feet, it becomes the really *"raging canawl"* of our derision. A dredging net of suitable length and strength is almost practically certain to bring up stones, large and small, covered with all varieties of the fauna I have already mentioned. These stones are placed in glass jars of from ½ to 2 gallons content, and, occupying places upon my table in a moderately warm room, rarely fail to supply me with a healthy stock for several months.

It is possible that the general students of zoology may be interested in a quotation from the paper referred to above, "Microhydra ryderii during 1907," describing the discovery of medusoid buds and their formation:

"It is possible that a few medusae were seen after their first discovery in 1897, say in 1898 or 1899, but no opportunity was found for such observation as was above suggested until May 16th of last year. On that morning a bud was doubtfully suspected, watched during that day and the next, and by 9 p. m. of the 17th the evidence of a coming medusa became convincing. Yet its position on the side of a jar, and in relation to the other members of the group, was not such as made possible the determination of the two points named above. The 'microscopical observatory' had not, at that date, been devised, and the best we could do was to stand the jar upon the side of which the budding medusa had been detected on a pile of books before a Welsbach gas light and examine it with

a Coddington lens or, later, through the tube removed from a compound microscope, and laid across another pile of books.

"This was the situation when, at 9.30 p. m., five of us determined not to lose sight of it during the night; wherefore one or more were continuously on the watch until 6.30 a. m. of May 18th. The first differentiation of parts had appeared about 9.30 p. m., May 17th, and all hands took part, though without artistic skill or scientific training in recording what we saw, by drawings, the most characteristic features of which I have here preserved. An examination of them will show the first recognizable feature to have been the *manubrium* at the proximal extremity of the bud—bearing upon its summit a circular or spherical form more or less complete in every figure, though variable in size; whose meaning must be left to elucidation through other specimens. Above or beyond this there was always a light-cavity of varying size and shape; and, almost from the beginning, transverse lines were to be seen at the distal end of the bud, suggestive of two membranes; and still more faintly longitudinal lines that ultimately resulted in becoming the *radial canals.* From 12.45 a. m. of May 18th and persistently thereafter, the innermost of the transverse lines mentioned gave convincing proof that it was to be the *velum,* including the marginal canal and circular aperture; and a few minutes later every observer noticed more or less distinctly, upon the outer membrane or surface, radial lines diverging from the apex or crown toward the position of the marginal canal, adjoining the velum. From 2.15 a. m. the approximately circular outline of the meduse changed to a pear shape, widening, with nearly straight lines, from the proximal to the distal end; and the faint lines of the radial canals became more marked. About 4.30 a. m. pulsation or throbbing of the velum was observed; at first a pair, *one, two;* then, say a half minute later, *one;* a pause, then, *one, two—one, two,* and so on, very irregularly; and thus continued, perhaps increasing in force until 5.30, when the *velum* with its aperture could easily be seen, distended, pressing up against and separating, at 6.20, the segmented tentacles as shown in two excellent drawings by Miss C. W. Beekley, as she saw them, parted, as when an orange is peeled

from any central point down to an equatorial line, and then forced upward by internal pressure.

"I know not what other observers may have written as to the formation of the earliest tentacles in marine medusa; but all our night watchers unhesitatingly agreed that my impressions of ten years ago had been proved correct, in relation to this species of freshwater forms. Of course, my theory assumes that the wider portions of these wedge-shaped segments contract, or, as it were, roll up upon themselves so as to form the nearly cylindrical tentacles as we know them. I place great weight upon the simultaneous appearance of the *whole eight,* without the slightest suggestion of longitudinal growth.

"The throbbings of the velum continued irregularly after the last drawing was made, finally liberating the medusa about 9 a. m. of the same day (May 18th). Two days had passed since the first determination of the bud, and the liberated medusa lived but two days longer, so that this specimen did not secure us any better sight of possible *sense organs* than had those seen ten years before."

EDWARD POTTS.

MUTATION IN MICRO-ORGANISMS

Dobell (Jour. Genetics, Nov. 1912 and Feb. 1913) gives a valuable review of the literature and a summary of the conclusions of investigators concerning mutation in micro-organisms.

In Trypanosomes (Nov., 1912,) it appears that definite structural changes may be produced by use of certain dyes, by cultivation in cold blooded vertebrates and certain invertebrates, which changes persist through subsequent divisions and apparently do not impair the power of division. In case of those treated with the dyes the kineto-nucleus is destroyed. The loss of this organ seems to decrease the virulence of the action of the Trypanosomes on the host. Virulence is changed also by the passage of the organism through the blood of certain animals. Resistance is developed by them also to certain drugs which are gradually administered. This increased resistance is transmitted in breeding.

In respect to the Bacteria, the author summarizes his digest in these words: "First it seems established that the Bacteria are

subject to mutation—that is to say, in a given race individuals may occur which differ from their fellows in their genetic constitution. Individuals frequently occur which possess new structural or functional features; and these features, though often the transient peculiarities of the individual only, are in some cases transmitted to the offspring for many successive generations. There is reason to suppose that this phenomenon occurs in nature as well as in laboratory cultures. The progeny of an organism which varies may thus constitute a new race, in which every individual possesses the new character."

The author defines mutation as a permanent change, however small it may be, which takes place in a micro-organism and is transmitted to subsequent generations. These mutations are classed as structural and physiological,—the latter comprising those in which the power of producing pigments, ferments, etc., is seen.

In some instances the mutations seem to be caused by chemical or other conditions of the medium; in others, in which effort was made to secure uniformity of medium, changes still occurred where it seems necessary to assume that the conditions of the changes were primarily internal.

DIFFERENTIATION IN CHROMOSOMES

Agar (Q. J. M. S. Dec. 1912) reports studies of chromosomes in Lepidosiren in which he shows that there is a widespread tendency for chromosomes to be constricted or to segment transversely. This is especially noticeable when the chromosomes are short in comparison with their length. The point at which this constriction takes place in a given chromosome is constant for that chromosome, and is the point at which it most readily tends to form the angle of the V when that form is taken. The author believes that the constancy of this position denotes a constant differentiation of the chromosomes *in* the long axis. The presence of the constrictions is not, however, necessarily to be considered as evidence of bivalency or of a future division in that plane.

BUD-FORMATION IN SYLLIDS

Potts (Q. J. M. S. Jan. 1913) proposes the following classification of budding found in these worms:—

1. Linear budding (terminal). Stolons produced at the end of the stock, and arranged end to end in chains, e. g. *Autolytus.*

2. Lateral budding. Stolons produced singly as lateral outgrowths from the stock. *Syllis ramosa.*

3. Collateral budding (ventro-terminal). Stolons produced from a ventro-terminal proliferating cushion on the stock, and arranged side by side in rows. *Trypanosyllis gemmipara.*

In this latter genus the author has made a study of the formation of the buds. The process is as follows:—The leucocytes collect in the mesoblast of the posterior segments where the buds are to appear; the epiblast gives rise to cell proliferations which begin the stolons; the mesoblast from the stock invades these young stolons; the mesoblast proliferates and shows its first signs of segmentation in the form of incipient septa; two bundles of muscle fibres and a single ventral nerve cord grow directly from the corresponding structures of the stock into the stolon; the epiblast of the stolon segments and forms its appropriate segmental structures.

Those who have studied the formation of new segments in the segment-forming zone of worms will be impressed with the similarity between the processes.

CORK OAK IN PORTUGAL

Klein (Naturwiss. Zeitschr. Forst- und Landwirtsch. Nov. 1902) discusses the cork oak and its products in Portugal in a very interesting article. As is well known this oak, *Quercus suber,* is native to Southern Europe. In Portugal there are some 550,000 acres of this oak. During the first 20 to 25 years its growth and cork production are rapid, and at the end of this period a crop may be gathered. The cork oak forests are mostly private property and are rented for periods of 20 to 40 years, or worked by the owner. The most of the old forests are natural; but of recent years new forests are being planted of acorns selected from known prolific trees. In such plantations the first crop may be had in 10 years.

MISTLETOE OF THE INCENSE CEDAR

Meinicke (Proc. Soc. Am. Foresters. Mch. 1912) has a very interesting study of the California mistletoe, which is parasitic on the Incense Cedar. This mistletoe is a small hanging shrub producing barrel-shaped swellings on the trunks of such trees as have been long infected. Account is given of the examination of some of these swellings as old as 350 years and 45 inches in diameter.

The living "sinkers" of the mistletoe were found 7/8 inch long, extending into the sap-wood and going through 19 rings. The dead "sinkers" were also to be seen persistent in the heart wood. In one tree at a point where there was no infection during the first 37 years, as shown by the inner rings, the last 219 years show continuous infection.

The parasite begins on the young tree as a semi-parasite with green leaves. The enormous development of the bark gradually eliminates both the green shoots and the aerial haustoria, and leaves the plant with a widespread root system extending into the tissues of the host, apparently without serious injury to it.

A SIMPLE METHOD TO REMOVE PARAFFIN SECTIONS WHICH ARE STUCK TO A SHEET OF PAPER OR TO THE HAND

Ribbons of paraffin sections temporarily set aside on a sheet of paper frequently adhere so firmly to the paper as to be undetachable without special means.

A simple method to remove such sections I have found to be as follows:—

Cut out a piece of the paper together with such a length of the ribbon as is desirable for mounting on one slide. Drop 50-75% alcohol on the piece so that the alcohol may diffuse under the paraffin sections. As soon as the paper underlying the ribbon is soaked with alcohol immerse the piece gradually in water. The ribbon will float off and may be drawn up on a wet slide and mounted in the usual way.

In cases where sections accidentally adhere to the hand, drop some alcohol so that it may diffuse under the sections. They may then be easily removed.

ROBERT CHAMBERS, JR.,
Biological Department, University of Cincinnati.

TO KILL MOSQUITOES OR OTHER INSECTS

Mix equal parts of 90% alcohol and a 1:500 aqueous solution of $HgCl_2$. Gently boil the insect in this for a minute or two to expel the air in the tracheæ. As the solution cools it is drawn through the stigmata into the body of the insect to all the tissues. Leave for a few hours, then pass at proper intervals through 90% alcohol, absolute, oil of turpentine, and paraffin.

R. Ross says this is particularly good for salivary glands of infected mosquitoes, as the Sporozoa are well preserved.

In case it is desired to mount whole a larva or small adult insect, after killing as above, use Farrant's Medium. Ring with Hollis' glue.

Abstracted by V. A. Latham.

TO KEEP SLIDES AT CONSTANT TEMPERATURE

Use a sheet of copper 15 inches long, 3 inches broad, and 1-12 inch thick. Support on 2 or more suitable feet and place a small lamp beneath. In this way graduation of temperature can be had by varying the height, and at different distances from the heated point.

V. A. Latham.

SECTION CUTTING IN GELATIN BY FREEZING

Gaskell (J. Path. and Bact. July 1912) recommends cutting certain materials by freezing in gelatin rather than by the usual processes. It is claimed that it avoids distortion such as occurs in use of fluids like alcohol and xylol, and also the vacuolation found in paraffin preparations. The fats are of course preserved. It is valuable in examining small objects, and objects with loose tissues like lung and tissues liable to disintegration. It is especially useful in examination of lung in broncho-pneumonia, as the contents are preserved *in situ*. Many other similar occasions of usefulness are cited. It prevents the disintegration often resulting from ordinary methods in pancreas, liver and spleen and the like.

The most important item is to get the proper consistency of the gelatin.

Fix in some formal mixture, as 10% formalin in Müllers fluid; wash thoroughly (over night or equivalent time), as formol will act on the gelatin and prevent penetration.

Tear up and soak Gold Label gelatin in water from 1 to 4 minutes, depending on room temperature. Squeeze the gelatin by hand, place in beaker, cover and melt in paraffin oven till viscid.

Transfer to ordinary incubator at 37° C., take tissue from water, dry or blotting paper, drop into gelatin, and leave for 2 hours.

Imbed the tissue in a paper box in some of the gelatin in which it has soaked. Let the mass set at room temperature. Harden for 3 or 4 days in vapor of formol, supporting above the fluid in suitable way. It may be left in this state indefinitely, or be stored in 5% formol. Return to the vapor for a few days before cutting.

When ready to cut pare the block and place in water 1-10 minute, depending on hardness, before freezing. The freezing microtome recommended is one by Aschoff made by Sartorius of Göttingen.

Various methods of successful staining are also given.

Abstracted by V. A. L.

HOUSEHOLD BACTERIOLOGY

This book is the outgrowth of courses in the subject given in the department of Home Economics at the Iowa State College of Agriculture. It is somewhat more than its name implies. It is rather a study of micro-organisms from the point of view, first, of the general student, and, second, of the student of the economic and sanitary applications.

The treatment is compact, and the authors succeed admirably in securing an intelligible discussion of an enormous number of phases of the subject. It appears to the reviewer as one of the most teachable of the books on the subject of economic microbiology.

After an overbrief opening chapter introducing the subject in a historic way, Sections I-III, consisting of 19 chapters, follow, dealing with the general considerations (I) of Morphology and Classification; (II) of the Technic of Culture, Sterilization, and

observation of Micro-organisms, and (III) of their Physiology and Ecology. In addition to the chapters on classification, which are remarkably clear and helpful to the beginner, an illustrated key of some 35 pages is given for the identification of the families and genera of the common molds. This without a doubt will add greatly to the usefulness of the book to the college student and to the independent worker. The authors have done for these household micro-organisms exactly what the American Microscopical Society is trying to do for the common genera and species of microscopic and near-microscopic plants and animals, on behalf of its members. They deserve the thanks of teachers for this contribution to the teaching of this interesting subject.

Section IV deals with *Fermentation* both from the scientific and the economic viewpoint. It treats the general phenomenon of fermentation, enzymes of micro-organisms, relation of these to food preservation, the changes in organic substances as sugars, milk, celluloses, gums, fats and nitrogenous compounds through the action of micro-organisms.

Section V treats of Micro-organisms and Health. Here are included the expected subjects: Theories of disease, resistance of the body to disease, organisms normal to the body, classification of disease-producing organisms, the various special types producing special disturbances in the body. In addition there are chapters on water contamination, examination and purification; contamination and examination of air; contamination and examination of milk and of other foods.

Household Bacteriology; Buchanan. Cloth, 8 vo., 536 pages and index. Illustrated. The Macmillan Co., New York. 1913. Price $2.25 net.

NECROLOGY

George C. Crandall, M. D.

Dr. George C. Crandall of St. Louis, Mo., who became a member of the American Microscopical Society in 1904, died recently at the age of 47 years, from Bright's disease, after an illness of two months.

He was born at Elgin, Ill., received his education at the University of Michigan, and began the practice of medicine at St. Louis in 1895. At the time of his death he was Professor of General Medicine in the Medical Department of St. Louis University, was president of the consulting staff of the City Hospital, medical director of the St. Louis Society for the Relief and Prevention of Tuberculosis, a member of the St. Louis Medical Society, Missouri State Medical Association, American Medical Association, Medico-psychological Association, Academy of Science, Civic League, Citizens' Industrial Association, and various social and business clubs.

He is survived by Mrs. Crandall, who was Miss Nellie Merry of Syracuse, N. Y., and one son, 16 years of age.

A. B. Aubert

Professor Alfred Bellamy Aubert was born in New York City in 1854. He was educated in the Columbia grammar school, in the Lycee of Strasburg, France, and received his B. S. in chemistry at Cornell University in 1875. Upon graduating from college he was appointed to the Chair of Chemistry at the University of Maine, which position he held for thirty-five years, retiring June, 1910, on account of failing health.

On assuming his position at the University of Maine, chemistry was taught only as a culture study, but through his efforts

a strong chemical course was developed, from which a large number of well-known chemists have been graduated.

As a teacher he had the ability to inspire in his students the utmost confidence. He was a member of several chemical and microscopical societies, to whose journals he contributed many interesting and valuable articles. As a man he was modest, retiring and unassuming, diffident almost to bashfulness, respected and beloved by all who knew him.

His death occurred November 12, 1912.

Bonner N. McCraven

Mr. Bonner McCraven of Houston, Texas, who joined the society in 1904, died during August, 1912.

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Herbert Osborn, M.S., of Columbus, Ohio,
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A. E. Hertzler, M.D., of Kansas City, Mo.,
at Washington, D. C., 1911.

F. D. Heald, Ph.D., of Philadelphia, Pa.,
at Cleveland, Ohio, 1912.

The Society does not hold itself responsible for the opinions expressed by members in its published *Transactions* unless endorsed by special vote.

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TRANSACTIONS
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THE SPENCER-TOLLES FUND

The Spencer-Tolles fund was established by the American Microscopical Society for the encouragement and furtherance of research, especially among its members and in lines of study in which the microscope is the principal instrument of research. While the total has not yet reached the limit desired to give an income effective for the purposes which the founders had in mind, yet the committee to whose charge the Spencer-Tolles fund was entrusted feel that the amount of the fund is now sufficient to warrant the society in appropriating regularly some part of the income for the encouragement of research while the remainder will still be added to the principal until the fund is completed. In order that the Society may be familiar with the situation and with the conditions laid down for securing appropriations from the fund the committee has formulated the following rules for its guidance in making grants. These received the approval of the Executive Committee at the annual meeting last December. They are intended to guide the committee in its action until experience demonstrates the advisability of changes; but they will not be modified without due notice to the Society and adequate opportunity for discussing from every standpoint any proposed alterations. The present financial status of the Spencer-Tolles Fund may be ascertained by consulting the report of the Custodian (Trans., v. 32, p. 86), and its growth is readily seen by comparing these reports for a series of years. They are published annually and give a full account of the Fund to date of the meeting.

It is not the intention of the committee to hamper the investigator by limiting the use of grants to very precise purposes or to control narrowly their expenditure, but to allow the fullest freedom for the exercise of individual judgment in particular cases. As

appropriate purposes in definite cases are recognized the collection or preparation of material for work, the construction or purchase of special apparatus, provision for field expenses, payment of services for control, observations or experiments, and the preparation of illustrations or other special expense incident to the publication of the research in proper form. Since the amount now available is small the committee is inclined to favor those definite purposes which may be served by the appropriation of smaller sums and is especially favorable to making such a grant in connection with funds available from college, university, or private sources where it will enable the investigator to complete a task already begun or to publish work already finished but delayed by the expense of printing.

In this connection attention is directed to grants already made from this Fund. No one of them was large enough alone to attain the results actually achieved, but in each case the completion of the work would not have been possible without such assistance as the Fund gave. In view of the large sums dispensed by other scientific organizations for experimental purposes in research the committee believes that aid in this direction is less needed, and is inclined to emphasize the aid to publication which it is in position to offer and which is not often given by other agencies. For the present, the committee will not limit its grants exclusively to those given to aid in the publication of research papers, even though it feels the need of such aid and the great advantage which will accrue to the entire Society as well as to the individual member by adopting such a policy.

REGULATIONS GOVERNING GRANTS FROM THE SPENCER-TOLLES EUND

1. The Committee will receive formal application for grants from the Spencer-Tolles Fund at present only from members of the American Miscropical Society.

2. Under ordinary circumstances not more than $100 will be voted in any one year to research purposes. Under the Constitution of the Society no money can be granted for any other purpose from the income of this Fund.

3. Applications for grants shall be filed with the chairman of the committee, who shall at once communicate all the facts to other

members and after their discussion and action shall inform the applicant of the result.

4. Each applicant shall submit to the committee a record of his professional or academic training and of any other research work already done. He shall name three persons qualified to speak through personal knowledge of these facts, especially concerning his ability to carry on investigation successfully.

5. Each applicant shall outline the topic on which he seeks the assistance of the Fund and shall indicate the manner in which he proposes to expend the grant asked, the reasons for seeking aid, and the results he expects to attain by this aid.

6. On completion of the work each recipient of a grant shall give the committee a report of the use to which the grant allowed has been put, preferably in the form of a paper ready for publication and embodying the results of the work in connection with which the grant was used.

7. Every grant is made upon the express condition that all results obtained by its aid shall be offered to the American Microscopical Society for publication in advance of their announcement elsewhere. In case the Society or its properly constituted authority is unable or unwilling to undertake the publication of the complete work, then permission will be granted to publish elsewhere; but wherever published publications including the results of this work shall contain the distinct statement that the work contained in the paper was done with the aid of a grant from the Spencer-Tolles Fund of the American Microscopical Society.

8. Payment of a grant shall be made by the Custodian on certification of the chairman that the committee has approved the grant and in accord with the specifications made by the committee for this particular grant. Payment of any sum will ordinarily be made, one half when the grant is approved and one half when the report is received and accepted by the committee. But the special circumstances associated with an individual grant may lead the committee to modify this rule and provide some other manner of payment in that instance.

9. The expenditure of the money shall be entirely in the control of the person receiving the grant and he shall not be asked to

secure or furnish any vouchers covering the expenditure in detail. On completion of the work he shall file with his report a statement that such a sum, mentioning the amount, has been expended and the results of the work are contained in the accompanying report. Any unexpended balance retained by the custodian in making the final payment, or if paid out of the grant not covered by this statement shall be returned to him and shall be again placed in the Fund.

(Signed) HENRY B. WARD, *Chairman*
S. H. GAGE
MAGNUS PFLAM
H. R. HOWLAND
A. M. BLEILE

NOTES ON THE TREMATODE GENUS CLINOSTOMUM

By William Walter Cort*

During the fall of 1911 I found encysted in the mesentaries and under the peritoneum of several specimens of the leopard frog *(Rana pipiens)* a number of larval distomes belonging to the genus *Clinostomum* Leidy. Recently more cysts were found in a frog of the same species from North Judson, Indiana. Two specimens of this genus from cysts in the black bass *(Micropterus* sp.*)* near Washington, D. C., were sent me by Dr. B. H. Ransom, and some of the same kind of material was given me by Dr. George R. La Rue, which he had found in perch *(Perca flavescens)* from Douglas Lake, Michigan. Additional material of the larval stages of this genus was turned over to me by Professor Henry B. Ward from his private collection. This material was from the following hosts and localities: From cysts in frog, Oshkosh, Wisconsin; from perch *(Perca flavescens)* and blue gill *(Lepomis pallidus)*, Bass Lake, Michigan; from rock bass *(Ambloplites* sp.*)*, Alma, Michigan; from perch, Lake Spooner, Wisconsin; from black bass *(Micropterus* sp.*)*, Sebago Lake, Maine. Also two adults were collected from the mouth of a black-crowned night heron *(Nycticorax nycticorax naevius)* which was taken alive near Urbana, Illinois, and given me by Professor Frank Smith.

I wish to express my appreciation of the helpful suggestions and criticisms given me by Professor Henry B. Ward during the preparation of this paper.

During the past year I have been engaged in a comparative study of the above material. Two recent papers by Osborn on the North American representatives of the genus *Clinostomum* have covered much the same ground as my studies. The first of these (Osborn, 1911), considers the distribution and behavior of this type of trematodes, and goes over the literature thoroughly. The second

*Contributions from the Zoological Laboratory of the University of Illinois, under the direction of Henry B. Ward, No. 25.

(Osborn, 1912), takes up their anatomy in so much detail that further morphological description seems unnecessary at the present time. Although in the main my observations confirm Osborn's, I must dissent from his conclusions in regard to the forms from the frog. Osborn finds so little difference in form and proportions of the body between the late immature stages from cysts in the fish and frog and the mature worms from the heron, that he considers all the flukes of this genus so far collected from North America to belong to the same species, *Clinostomum marginatum* Rudolphi. I find that the specimens from the frog show so many differences that I am forced to consider them as a distinct species. The *Clinostomum* from the bittern (Wright, 1879) also shows several important points of difference from the adults from the heron, and is probably the adult stage of the frog species.

Distomum reticulatum described by Looss (1885), a larval *Clinostomum* from Costa Rica (not Porto Rica, as stated by Osborn and Linton), has given rise to considerable discussion. This form is much larger than any of those from North America, has a lobed ovary, and the cirrus sac extends to a point posterior to the posterior testis. Osborn (1912: 219-220) doubts whether these differences are great enough for specific distinction, and states that too much importance should not be attached to differences in shape of an organ like the uterus or its parts. He further states that writers from Leuckart down have considered *Distomum reticulatum* Looss to be identical with the North American representatives of the genus *Clinostomum*. This statement is not correct since Braun (1900: 44-45) states that *Distomum reticulatum* is distinct from the North American species, and relates the former closely to *Clinostomum sorbens*, a South American species which he described. I agree with Braun's conclusion. Since Looss' name for this form was preoccupied Monticelli renamed it *Mesogonimus dictyotus*. But he overlooked Leidy's earlier genus *Clinostomum;* therefore Looss' Costa Rican trematode should be known as *Clinostomum dictyotum*.

In the study of the North American representatives of *Clinostomum* very little attention has been given to those from frog hosts. MacCallum (1899) reports them, and Osborn (1911) describes their position in the cyst. He also includes them in his later paper

on the structure of *Clinostomum marginatum,* although apparently all his anatomical descriptions and figures represent specimens from the black bass and heron. Both the above authors have referred this form to *Clinostomum marginatum.* I propose to show that the *Clinostomum* form from the frog belongs to a distinct species, which may be named *Clinostomum attenuatum,* since it is the most slender of all the species so far described in this genus.

The late larval stages of *Clinostomum attenuatum* have been found encysted only in frogs, and of *Clinostomum marginatum* only in fish. The cysts in the frogs are scattered in the mesentaries, embedded under the peritoneum of the body cavity and in the lymph spaces between the skin and muscles of various parts. They are never found within the muscle tissue surrounded by its fibers. The cysts from the fish in my experience and Osborn's are always found in the midst of muscle bundles.

Osborn (1911) notes the position of the worm in the cyst as the only difference between the forms from the fish and frog. I have found this condition to be dependent upon the location of the cyst. In those cysts embedded in the muscles of the fish where there is considerable pressure from all sides, the worm is folded three times with the acetabulum to the outside and is very tightly enclosed by its cyst. Where the cysts are loosely held in the mesentaries of the frog and subjected to little if any external pressure, the worm is very loosely enclosed in its cyst, and is usually folded but once. But in those cysts which are located in the frog where they are subjected to pressure as between the large muscles of the upper thigh, the worm is folded three times and compressed tightly in its cyst, offering then much the same appearance as the fish cysts.

Differences are to be noted between the two species in size and shape. In length the range of variation within each species is so great that no constant difference is found. The specimens from the frog ranged from 3.9 mm. to 5.52 mm. in length. Among those from the fish the smallest individual measured 3.5 mm. and the largest 6.6 mm. in length. In body shape the differences are very distinct and constant. The frog type is slender and of almost uniform width and thickness throughout its length (Fig. 1), while the fish type has a broad rather flat post-acetabular region (Fig. 2). In *Clinosto-*

mum attentuatum the pre-acetabular region is oval, measuring on the average about 0.67 mm. in width by 0.41 mm. in thickness, while the whole body back of the acetabulum has a thickness greater than half its width. The average measurement for the region of the ovary are about 0.68 mm. in width by 0.37 mm. in thickness. In *Clinostomum marginatum* from the fish cysts the pre-acetabular region is more nearly cylindrical, the average width for my specimens being 1.05 mm. and the average thickness 0.85 mm. Just back of the acetabulum the ratio of the width to the thickness is about three to two, the average width being 1.35 mm. and the average thickness 0.91 mm. At the ovary, however, this worm is wider and more flattened than the other species, having an average width of 1.55 mm. and a thickness of 0.71 mm. The difference between these two species in relative width of the different body regions is even more pronounced. In the frog forms the width of the pre-acetabular region is equal to or only a little less than that of the post-acetabular, while in the fish forms it is only a half or two-thirds as great. In the first species the post-acetabular region has about uniform width throughout its length, while in the second it is considerably wider at the ovary than just back of the acetabulum, and becomes narrower toward the posterior end. These relations are illustrated fully in the measurements given in the table.

Braun (1900), in his diagnosis of the species of *Clinostomum* lays considerable emphasis on the structure of the anterior tip. This region is truncated obliquely ventrad so that the dorsal surface extends somewhat further forward than the ventral. Braun calls this surface the oral field. In the center of this field on the oral cone is the oral sucker. Surrounding the oral cone in both *Clinostomum attenuatum* and *Clinostomum marginatum* is the furrow and the projecting margin described by Braun in some of the species of this genus. Braun's suggestion that the whole oral field is used as a sucker has been confirmed by Osborn (1911: 368), and is fully discussed later in this paper. In *Clinostomum attenuatum* the oral cone fills a greater portion of the oral field than in *Clinostomum marginatum,* whereas in the latter the furrow is deeper and wider and the projecting margin higher. Measurements of four individuals of like contraction express the first difference. In two

specimens from the frog the oral cone measured 0.45 mm. and 0.52 mm. in diameter at its base, and the oral field had a width of 0.56 mm. and of 0.65 mm. making the ratio very nearly 4:5. But in two specimens from the fish the oral cone measured 0.60 mm. and 0.67 mm., and the oral field 0.93 mm. and 0.97 mm. in diameter, the ratio in this case being about 2:3.

Further differences between these species are found in the relation of the length of the pre-acetabular region to the total length of the body, and in the position of the genital glands. In *Clinostomum attenuatum* the region in front of the ventral sucker is short, being only about one-sixth or one-seventh the total body length, while in *Clinostomum marginatum* it is one-fourth or one-fifth. To determine the position of the genital gland field the distance from the posterior edge of the acetabulum to the ovary was measured. In the frog type the ovary is always back of the middle of the post-acetabular region, and in some cases the whole genital gland field is back of that point. In the fish type this condition is almost always reversed, the ovary in my specimens being at about the middle or in front of the middle of the post-acetabular region. Reference to the table will make these differences more clear.

In the genus *Clinostomum* the uterus empties into a sac which extends longitudinally from the genital pore anteriad toward the acetabulum (*u s* Fig. 1 and 2). In the larval stage this sac is very narrow and contracted. In both the species under consideration the uterine sac has about the same length, but its position in respect to the other organs is different. In *Clinostomum attenuatum* the distance from the posterior edge of the acetabulum to the anterior tip of the uterine sac is quite great, being almost equal to and in some cases exceeding the total length of the sac. But in *Clinostomum marginatum* the anterior tip of the uterine sac comes very close to the acetabulum and in the contracted specimens almost touches it.

Depending upon the great variation in size of the animals, the diameter of the suckers varies rather markedly in these two species. In spite of this variation distinct differences can be traced. In *Clinostomum attenuatum* the oral sucker measured on the average 0.19 mm. in transverse diameter and in *Clinostomum marginatum* 0.30 mm. The acetabulum in the first species measured on the

average 0.56 mm. and in the second species 0.73 mm. In the extreme individuals, however, the sizes overlap. The difference between these two species in the ratio of the size of the suckers is constant. In *Clinostomum attenuatum* the acetabulum is about three times as large as the oral sucker, while in the *Clinostomum marginatum* the ratio is about 2.4 to 1.

The most clear cut specific difference between these two forms is found in the difference in the structure of the cuticular spines. In *Clinostomum attenuatum* the spines range from 0.013 mm. to 0.016 mm. in length and from 0.005 mm. to 0.009 mm. in thickness at their bases, and in *Clinostomum marginatum* they vary in length from 0.007 mm. to 0.011 mm. and in thickness from 0.0015 mm. to 0.002 mm. In both species they are about equally numerous in a given area but on account of their greater width they appear more thickly set in the flukes from the frog. Figures 4 and 5 show this difference in size more clearly than any description.

The differences given above between the advanced larval stages from the frog and from the fish seem to me to be so distinct and so far reaching, that it is impossible to consider these two forms as belonging to the same species.

MacCallum (1899) and Osborn (1912) have worked out the anatomy of the adult *Clinostomum marginatum* from North America in considerable detail, so that I shall give only a sufficient description of the specimens collected from the black-crowned night heron to determine their relationship to the larval forms. The following measurements were taken from the worm shown in figure 3:

Length	3.4	mm.
Width at the anterior end	0.67	"
Width half way from the anterior end to acetabulum	0.63	"
Width at acetabulum	0.56	"
Width half way from acetabulum to ovary	0.82	"
Width at ovary	1.02	"
Width half way from ovary to posterior end	0.97	"
Length of pre-acetabular region	0.97	"
Length of post-acetabular region	2.46	"
Distance from acetabulum to ovary	0.87	"
Distance from ovary to posterior end	1.4	"
Length of uterine sac	0.45	"
Distance from anterior tip of uterine sac to acetabulum	0.07	"
Length of genital gland field	0.76	"

Transverse diameter of oral sucker	0.17	"
Transverse diameter of acetabulum	0.39	"
Ratio of oral sucker to acetabulum	1 to 2.3	"
Length of eggs (average)	0.091	"
Width of eggs (average)	0.051	"

These measurements agree so closely with those given above for the advanced larval stages from the fish that both forms must be considered as different developmental stages of the same species. This adult was very small and in length and size of suckers falls slightly below the smallest of the larval forms. The anterior end is more attenuated in the adult than in any of the larval forms which I examined, but this is due to difference in contraction. On the other hand it can be seen that the larval stage from the fish and the adult from the heron are almost exactly alike in the general shape of the body, the proportions of the various regions, the position and configuration of the genital organs, and the ratio in size of the suckers.

Osborn's description of *Clinostomum marginatum* from the bass and heron agrees in all points with my forms from similar hosts. Since he observed more individuals he notes a greater range of variation than was found in my material. His worms vary in length from 3 mm. to 8.2 mm. and in greatest width from 0.7 mm. to 2.2 mm. It is of interest to note that Osborn (1912: 191) also finds his smallest individuals among the adults, indicating a still greater variation than he has found for the larval stages.

That the fluke described by MacCallum (1899) as *Clinostomum heterostomum* is really *Clinostomum marginatum* cannot be doubted. He notes individuals up to 10 mm. in length and in his drawing of a toto preparation the ovary is back of the middle of the post-acetabular region. In all other respects his description of this worm agrees with Osborn's and my own for *Clinostomum marginatum*. These observations and comparisons seem to show that all the representatives of the genus *Clinostomum* which have been found up to date in North American fish and herons belong to the one species, *Clinostomum marginatum*.

Clinostomum marginatum was originally found in Brazil. Braun (1900) compared Rudolphi's type specimens of *Clinostomum marginatum* from Brazil with material gathered by Natterer in the same country from several different localities and hosts. He states that

all this material corresponded so closely to Rudolphi's type specimens that it must be considered as belonging to *Clinostomum marginatum*. After a careful comparison with Braun's descriptions, I can find no constant differences between the North American forms just considered and these Brazilian forms except in the greater size of the eggs of the latter. In the specimens from South America the eggs vary in length from 0.104 mm. to 0.140 mm. and in width from 0.055 mm. to 0.073 mm. The largest measurements recorded for the eggs of North American forms is 0.099 mm. in length by 0.066 mm. in width. It will be seen that in width this falls well within the range of variation of the South American flukes, and is only slightly less in length. Braun's material from Brazil agrees so exactly with Osborn's and my specimens from North America, that his figures 8, 9, or 20 (Braun 1900), might be used to illustrate our descriptions.

Clinostomum marginatum is thus a species of very wide distribution, having been reported from Brazil in South America, and from North America very widely. It has also a wide range of hosts. The advanced larval stages have been reported from cysts in the pike, the perch, the blue gill, the black bass, the rock bass, the sunfish and the trout. The adult has been found in three different genera of water birds: From three true herons, *Ardea* sp. (Brazil), *Ardea cocoi,* and *Ardea herodias;* from one species of stork, *Mycteria americana,* and from the black crowned night heron, *Nycticorax nycticorax.* The presence of *Clinostomum marginatum* in both North and South America is easily explained by the great range of of the adult host. *Ardea herodias* and *Nycticorax nycticorax naevius* for example both range over North America at large, and central and northern South America.

There remains for consideration the *Clinostomum* described by Wright (1879) from the American bittern. Wright's description and drawing of this form differs in several respects from *Clinostomum marginatum.* In his drawing the genital field is shown behind the middle of the post-acetabular region, the uterine sac reaches only about half way from the genital pore to the acetabulum, the pre-acetabular region is only about one-sixth of the total body length, and the worm is rather long and slender with fairly uniform width

throughout. All these points agree with *Clinostomum attenuatum* rather than *Clinostomum marginatum*. Since frogs form an important part of the food of the American bittern, Wright's *Clinostomum* from this host might well be the adult *Clinostomum attenuatum*.*

While collecting two adult *Clinostomum marginatum* from the heron, I was able to make some observations on the activity and relation to its host of the living parasite. The two flukes were below the average in size for this species and had only a few eggs in their uteri. The activities of the parasite were studied both while in the mouth of the heron, and after removal into normal saline solution. The heron came into my hands still alive and not more than five minutes elapsed between the killing of the bird and the finding of the flukes.

In the bird's mouth the worms were very much contracted, and adhered so firmly to the mucous membrane that it was very difficult to loosen them. Their position was well suited to resist the friction of food taken into the mouth of the heron. Not only was the acetabulum firmly attached but also the oral field functioned as a sucker. The pre-acetabular region was bent over so that the oral field was almost in contact with the acetabulum. The anterior end was given very firm attachment by the sucking action of both these structures. The post-acetabular region was much contracted longitudinally and arched so that it was quite convex. The edges were pressed closely into the mucous membrane, and evidently by the drawing up of its central part this whole region also acted as a sucker. In fact the posterior end was so firmly attached that it was almost as difficult to loosen as the anterior. Such a sucking activity of the post-acetabular region accounts for the great development of

*Since the completion of the above observations I have received from Professor Henry B. Ward material of the genus *Clinostomum* collected by A. L. Cooper from the vicinity of Go-Home Bay, Toronto, Canada. This material, which was both larval and adult, was collected from two fish hosts—*Perca flavesens* and *Micropterus dolomieu*,—one frog host—*Rana catesbiana*,—and one bird host—the American herring gull (*Larus argentatus*). A careful examination, using for species determination the points brought out above, showed that the specimens from the fish and bird belonged to the species *Clinostomum marginatum*, and the form from the bull frog to *Clinostomum attenuatum*. This gives additional data to support the hypothesis, that *Clinostomum marginatum* in its advanced larval stages is limited to fish hosts and *Clinostomum attenuatum* to frogs. Also this collection adds a new genus to the bird hosts of *Clinostomum marginatum*, and extends the list of hosts of *Clinostomum attenuatum* to two frog species.

the dorso-ventral parenchymous muscles which has been noted for this species.

The only reference in literature to the position of the *Clinostomum* in its bird host is by Osborn (1911: 363). He found specimens of *Clinostomum marginatum* adhering to the heron's throat only by means of the anterior end. As the bird had been dead for a day or two, the worms were probably beginning to loosen their hold. In his later paper on this form Osborn (1912: 193) writes as if attachment in this species was effected by the anterior end alone. He says that the reason for the large size of the ventral sucker had not been indicated by the behavior of the worm, and that although the structure of this sucker suggests full functional power he had noticed no activities for it. My observations show that the acetabulum is not only fully functional in this species, but that it plays a very important part in holding the parasite in position in the mouth of the host.

After the position of the worms had been noted they were removed and observed for some time in normal saline solution. The living fluke was a semi-transparent whitish cream color, with the testis and ovary showing as opaque pure white areas. The intestinal ceca were dark brown, and the region surrounding the uterine sac was light pink. The animal manifested considerable activity (Figs. 6 and 7), the whole body expanding and contracting rythmically. In its most contracted state the total length of the worm was about 2.5 mm. with a width at the region of the ovary of 1.56 mm. When most extended it reached a length of 4.96 mm. with a width at the ovary of 0.92 mm.

A study of the movements of the worm after removal from its host confirmed the observations made on its sucking activities while in position, and suggested a possible method of locomotion. This fluke has the long distance from the stomach to the mouth of the bird to travel, after the larval forms have been freed from their cysts in the fish by the digestive juices. In the most contracted position the anterior end was much shortened and turned ventrad, the oral field with the oral cone at its center being in the same plane and very close to the acetabulum. The edge of the oral field was very mobile and strong sucking movements were noted. This posi-

tion of the anterior end suggests that which was noted when the animal was attached to the mucous membrane of the heron's mouth. In the contracted position the post-acetabular region was very short and broad and so arched up as to be very thin. The edges showed considerable movement, curling in and then extending. The position and movements of this region suggested that if its edges were in contact with a soft surface considerable sucking power would be developed, just as in a small boy's leather sucker. This position of greatest contraction I shall call the sucking position. It was the assumption of this sucking position which made the removal of the worms from the mucous membrane of their host so difficult. The need of such a strong sucking reaction on the part of the parasite is apparent, when it is considered that whole fish and other very hard particles of food are taken into the mouth of the heron.

In the series of rythmical contractions made by this fluke as it lay free in the salt solution was suggested a possible method of locomotion. The cycle of expansion and contraction was as follows: From the sucking position the pre-acetabular region would stretch out and the oral field go through sucking movements. At the same time the post-acetabular region would be extended, reaching its greatest length just as the pre-acetabular region was beginning to contract. The worm would then contract again into the sucking position and a new cycle of movement would be initiated by the extension of the anterior end. Sucking movements of the acetabulum were noted during this process.

When the larval trematodes incysted in a fish eaten by the heron are liberated in its stomach by the action of the digestive juices, they turn toward the esophagus. The series of rythmical movements described above is begun, and when the pre-acetabular region is extended and turned ventrad, the oral field comes in contact with the mucous membrane. The sucking movement causes it to take hold and on the contraction of the pre-acetabular region, the worm is pulled forward until the acetabulum comes into close contact with the oral field. The acetabulum then takes hold in its turn and on the next extension of the anterior end holds the ground gained. By a laborious repetition of these movements the worm could make its way up to its final position. If any food coming

down the esophagus should strike the parasite it would contract strongly, assume the sucking position, and hold on with its whole body until the way was clear again. Having once gained its final position, the adaption of the whole body for sucking would enable it to hold its position against the friction of the heron's food.

TABLE OF MEASUREMENTS

	Clinostomum attenuatum					*Clinostomum marginatum*				
	1	2	3	4	5	1	2	3	4	5
Length	5.8	5.18	3.9	4.35	5.8	6.4	6.6	4.1	3.5	4.09
Width at anterior end	0.58	0.52	0.54	0.52	0.69	0.93	1.02	0.74	0.6	
Width half way from anterior end to acetabulum	0.84	0.71	0.61	0.61	0.86	1.2	1.3	0.89	0.78	0.96
Width at acetabulum	0.80	0.67	0.63	0.69	0.80	1.3	1.4	0.99	0.84	0.93
Width half way from acetabulum to ovary	0.84	0.67	0.61	0.60	0.93	1.5	1.54	1.17	0.89	1.17
Width at ovary	0.84	0.71	0.62	0.71	0.89	1.6	1.7	1.2	0.98	1.25
Width half way from ovary to posterior end	0.91	0.71	0.61	0.65	0.91	1.48	1.6	1.15	0.9	1.14
Length of pre-acetabular region	0.74	0.65	0.61	0.71	0.74	1.12	1.28	0.84	0.71	0.89
Length of post-acetabular region	4.5	4.41	2.73	3.18	4.5	4.1	4.43	2.55	2.34	2.91
Distance from acetabulum to ovary	2.33	2.42	1.67	1.86	2.18	2.08	2.05	0.99	1.01	1.38
Distance from ovary to posterior end	2.18	1.99	1.06	1.32	2.33	2.06	2.38	1.36	1.34	1.55
Length of uterine sac	0.99	1.1	0.71	0.71	0.87	1.21	1.02	0.61	0.60	0.74
Distance from anterior end uterine sac to acetabulum	0.91	0.84	0.69	0.71	1.04	0.35	0.45	0.09	0.13	0.24
Length of genital gland field	0.74	0.95	0.56	0.63	0.78	0.94	1.08	0.65	0.60	0.71
Transverse diameter of oral sucker	0.19	0.17	0.17	0.17	0.22	0.33	0.41	0.28	0.24	
Transverse diameter of acetabulum	0.57	0.57	0.54	0.60	0.66	0.89	0.91	0.71	0.50	

The above table gives measurements from ten representative toto mounts, five of *Clinostomum attenuatum* and five of *Clinostomum marginatum.*

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EXPLANATION OF PLATE IX

Figures 1-5 were drawn with a camera lucida.

FIG. 1. *Clinostomum attenuatum* from *Rana pipiens*. Larval specimen. X 57.

FIG 2. *Clinostomum marginatum* from *Perca flavescens*. Larval specimen. X 57.

FIG 3. *Clinostomum marginatum* from *Nycticorax nycticorax naevius*. Adult. X 57.

FIG. 4. Cuticula and spines of *Clinostomum attenuatum*. X about 1000.

FIG. 5. Cuticula and spines of *Clinostomum marginatum*. X about 1000.

FIGS. 6 and 7. Free hand drawings of a living specimen of an adult *Clinostomum marginatum* expanded and contracted. X about 33.

ABBREVIATIONS USED IN PLATE

a, acetabulum
i, intestine
om, oral mound
o, ovary
os, oral sucker
t, testis
u, uterus
us, uterine sac
v, vitellaria

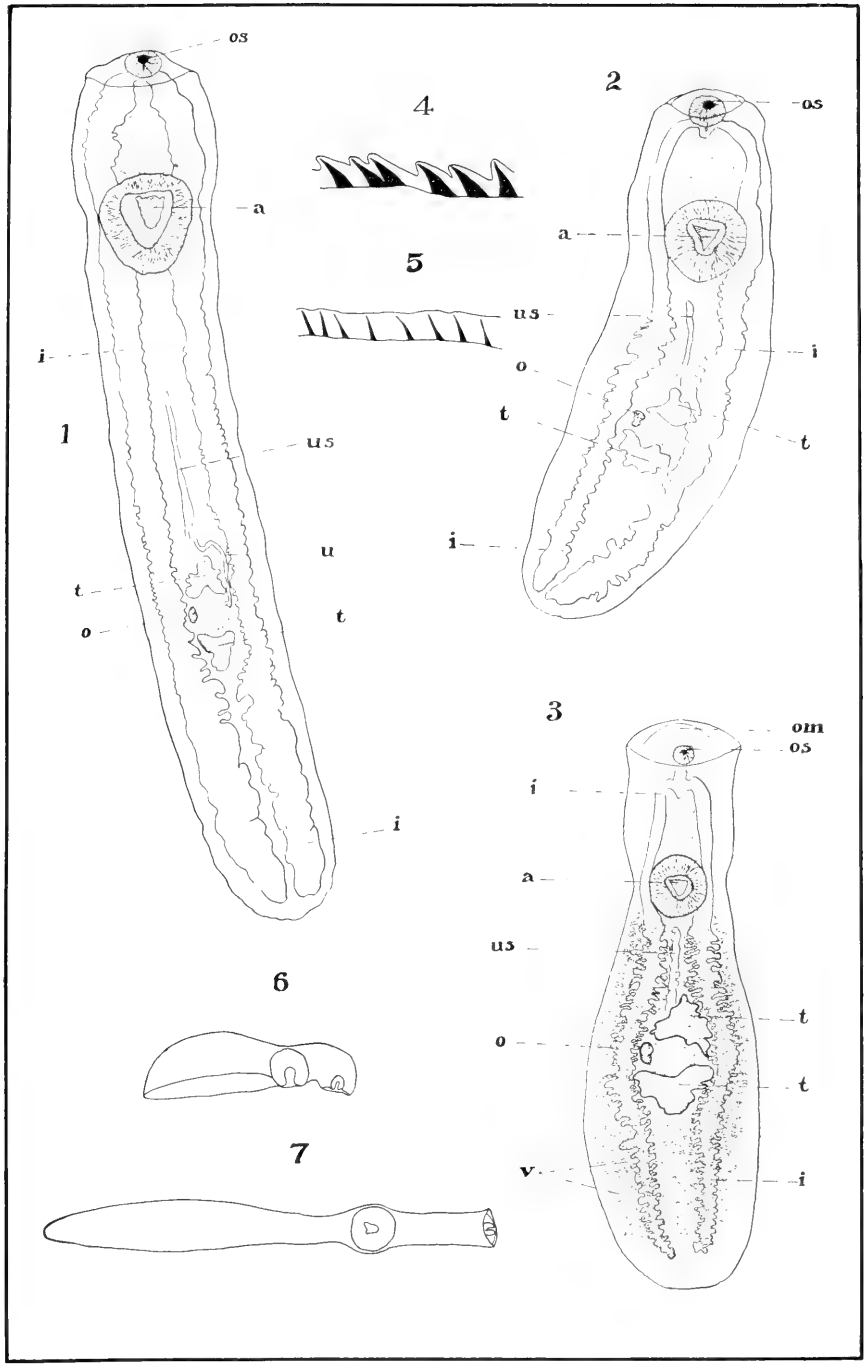


PLATE IX

DEPARTMENT OF NOTES, REVIEWS, ETC.

It is the purpose, in this department, to present from time to time brief original notes, both of methods of work and of results, by members of the Society. All members are invited to submit such items. In the absence of these there will be given a few brief abstracts of recent work of more general interest to students and teachers. There will be no attempt to make these abstracts exhaustive. They will illustrate progress without attempting to define it, and will thus give to the teacher current illustrations, and to the isolated student suggestions of suitable fields of investigation.—[Editor.]

AMATEUR MICROSCOPISTS

The following group of four notes, by Mr. Roberts, represent work done by an enthusiastic photographer, who is greatly interested in studying and photographing histological and cytological conditions. They represent a type of worker and of work which the American Microscopical Society wishes to encourage. So much expert work is done with the microscope in our great laboratories that too many students come to feel that good work cannot be done away from them. It is the hope that amateur workers will come more and more to use this department, and make it helpful to other amateurs.

I. NOTES ON RHIZOPODS FROM MICHIGAN

During the summer of 1912 monthly collections at the same locality were made. These collections were killed and fixed at early morning hours, stained in iron-hematoxylin, dehydrated and carried into xylol. Some of the material was mounted whole in balsam and other portions imbedded and sectioned.

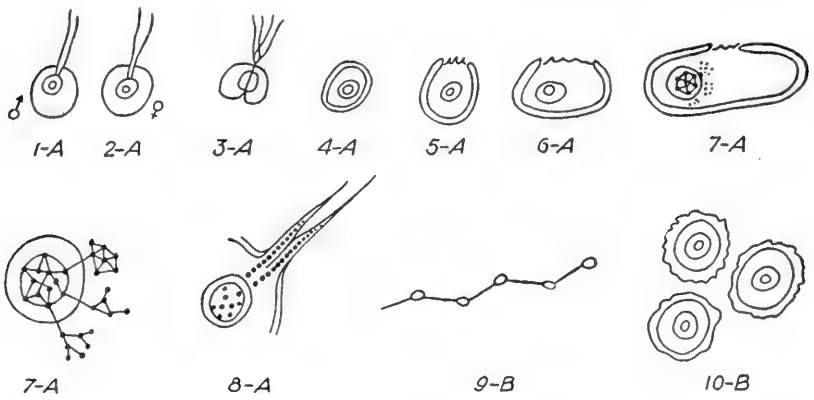
Many varieties were studied, but the common *Arcella vulgaris* was the easiest material for observation, both on account of its shape, ease of identification and number of individuals found.

The Arcella is very polymorphic in form, and has a number of different life phases which are not altogether understood.

The life cycle is a year in length, and the majority of individuals arrive at sexual maturity in May and June. From then onward only straggling mature individuals are found.

The ordinary method of propagation is by gametes. These are furnished with a pair of flagella by which they move about. See

Fig. 1-A and 2-A. These gametes are macro- or female, and micro- or male. They conjugate and form a new individual which, after a resting stage, develops into a mature Arcella. Along in October the young individuals begin to form the chromidial net from which the future generations are cut out.



1-A. Arcella—male gamete.
2-A. Arcella—female gamete.
3-A. Arcella—conjugation of gametes.
4-A. Arcella—resting stage.
5-A. Arcella—early vegetating stage.
6-A. Arcella—later vegetating stage.
7-A. Arcella—showing details of chromidial net formation.
There are 12 chromosomes which bud out chromidia into the cytoplasm, these subdivide and form the net.
8-A. Arcella—showing the formation of the flagella fibrils from the centrosomes.
9-B. Clathrulina in asexual series.
10-B. Clathrulina in resting spore stage—asexual.

This stage was observed as shown in Fig. 7-A in the diagrams. Certain chromidial bodies are budded out from the nucleus into the cytoplasm, where they undergo repeated subdivisions until their progeny form a dense network of deeply staining granules connected by threads which follow the divisions. This process continues slowly until the warmth of Spring hastens feeding, which increases nourishment and brings the metabolism of the organism to a climax.

When the net is fully formed it undergoes constrictions in the night, forming at intervals masses of the chromidial granules. See

Figs. 1 and 2, Plate X. The inclosed granules now bud out a certain number of granules which unite and form a nucleus for the mass.

The formation of the flagella by repeated divisions of centrosome bodies was observed. This agrees in all essential details with the later observations of the origin of motile organs on various type of plant and animal sperms. See text figure 8-A.

This end, bearing the flagella, is the mouth end of the adult rhizopods, so that in all forms, both naked and shelled, there is always a definite polarity or relation of the nucleus and cytoplasm. See Fig. 5-A.

The Rhizopods are now considered to be degenerate flagellates. The flagellate gamete stage gives the clue to their line of descent.

These sexual gametes escape when mature, leaving temporary scars in the matrix in which they were bedded, as is shown in Fig. 3, Plate X.

There was seen occasionally an alternate sexual generation, or process of schizogony. This stage or form is produced by the constriction of the chromidial net into masses. These masses have at this stage no nuclei, each mass being inclosed by a network of regularly placed granules connected by threads. These granules, bud inward, forming granules which group and form the new nucleus, while they themselves form the cytoplastids, or vegetative systems. See Fig. 4, Plate X.

Thus we see the cell formation processes reversed from the common method of budding from the nucleus outward. This seems to the writer to show that the chromidial elements of the cytoplasm are of the same rank as the nuclear chromidia, being capable of reversing their generations in either direction.

This seems to represent a degenerate function which is only repeated at rare intervals, as but very few are to be found.

Then there is a process of blastogamy, in which an individual deserts its shell and unites with another individual in its shell, the two forming a joint network. This chromidial mass later breaks up into swarm spores.

The peculiar markings on the chitinous shell are produced by cyto-somes, which take nuclear stains, and the membrane on which

the chitin is deposited is easily observed in many specimens where the individual is shrunken away from the wall by the reagents.

Many fine specimens of our only form of fresh water Polycistinæ, the Clathrulina, were found, and several interesting phases of their life history studied.

They form a fenestrated silicious shell on a long stalk, as shown in Fig. 5, Plate X. An interesting phase of their asexual reproduction was observed. The body divides, part escaping from the shell. This part then forms a new shell for itself. The stalk of the new individual forms in attachment to the old shell, and by growth gradually elongates until adult size is reached when the process is again repeated. As many as eight individuals were found thus formed a series. See text figure 9-B.

They also reproduce sexually by motile macro- and microgametes, which escape and conjugate and after a resting stage follow the usual route to maturity.

An interesting asexual stage was found, the body breaking down into three stellate resting spores, much resembling those of Desmids. See Fig. 6, Plate X. The cell wall is dissolved and the spores escape and are found in abundance in the mud.

As late as October they still remain in this stage, very likely spending most of the winter thus. Early Spring collections ought to show good stages of their development.

2. SPECULATIONS ON THE NATURE OF THE OLFACTORY ORGANS

In the vast families of insects and among other nearly related animals are found certain organs called antennæ. These are situated on the head and are generally conceded to be modified limbs, of which each segment of these forms of bodies once possessed a pair.

Such a modified pair of legs from a Black Syrphus Fly is shown in Fig. 1, Plate XI. Here, at least three segments of the limb remain. The second segment is greatly expanded laterally, forming a bulb much flattened, to which is attached the third segment in the form of a long whip-like filament.

This modified limb is supposed to be the seat of several senses; indeed, in some insects each segment is credited with a different function by some writers.

These limbs, originally used for walking, were doubtless provided with various sensory cells adapted to the necessities of their peculiar functions. The sensory cells are usually in the form of hypodermal spines of various shapes, covered with a chitinous exterior to give them greater firmness.

All the living cells of animal bodies are supposed by many students to be connected by minute filaments with the nervous system. Thus all cells are potential sensory cells, both those on the interior and exterior of the body.

By looking at the enlarged lobes of the antennæ of the fly in Fig. 1, it will be seen to be covered with small spines. Also there will be seen near the base a dark circular pit. On many insects these are very numerous and are considered as olfactory in function. These olfactory pits are invaginations of the hypoderm, and the spines on the exterior are sunk into the pits.

If we look at Fig. 2, which is a section of these pits on the antennæ of a fly, called Sarcophaga, we will see the pointed spines which are the sensory structures.

The sensory cells being thus sunk are much protected so that their chitin envelop may be but feebly developed, leaving them nearly naked and therefore more sensitive.

So we have here two kinds of sensory cells, the external exposed cells, and the sunken or protected cells.

It is apparently these same hypodermal spines which form the rhabdome rods in the optic invaginations of insect eyes.

If we now look at another form of limb called a palpus (See Fig. 3), from a moth, *Pieris raphae*, we will see the end of the organ is invaginated into a pit. Into this pit will be seen projecting the sensory scales, while below is the connecting nerve cord.

In Fig. 4 we get a view of the elaborate development of these pits on the antenna of a honey bee. Here the same spines are seen in the pits, also the elaborate nerve connections.

Figure 5 is a cross section of the olfactory pits on the antenna of a wasp, *Vespa*. The outer openings of these pits are closed by

elongated lips of chitin, while the pits proper are more round in shape. The naked tips of the sensory spine cells are seen in cross sections in great numbers. While these pits are regarded as olfactory, it may well be that the olfactory sense is not confined to the pit spines alone, but is only more sensitive here because of the thinness of the chitin. It may occur in some degree over the exterior.

On many Lepidoptera the males have these external sensory scales so well developed that they are enabled to pick up the trail of a female of their species by the scent she leaves in passing through the air. In such cases the antennæ are largely developed, while the shoulders and fore limbs also are covered with a special growth of scales which seem actively to function as olfactory organs.

A moth called *Chyfolisa morbidalis* has in the male a brush of enormous scales on each front leg, which exceeds the entire combined size of the head and antennæ. In this case the whole front of the body becomes a quivering agency of sex determination.

It seems reasonable that this is a case of animal tropism, the pathway of chemical particles left in the air by the female acting on the sensitive spines much as light acts on the eyes.

It is possible that this chemical sensitiveness to particles in the air is partly responsible for the irregular flight of such animals.

3. VAGINICOLA; AN INTERESTING PROTOZOAN

The form described herein is apparently related to the Vorticellidæ, a family of infusorians remarkable for beauty and variety. From their shape these animals are often called Bell-animalcules. They are attached, either temporarily or permanently, and often have a distinct stalk.

They are usually marked histologically by a long ribbon-shaped nucleus, a circle of vibratile cilia around the oral end, and by a lengthwise binary division as one of the methods of its multiplication.

The form described here was found June, 1912, in collections from Goguac Lake, near Battle Creek. It is free, has a capsule, seemingly of a chitinous or horny nature possessed of an oval aperture. In all the specimens studied there is a pair of individuals in each capsule.

Figures 1 and 2, Plate XII., are photographs of longitudinal and cross-sectional views, respectively, of the animal. Figures 3 and 4, Plate XII, are diagrams simplifying and interpreting the former figures. From these the main details of the anatomy can be made out.

The twin individuals arise apparently by binary division of the parent. Further multiplication is by motile gametes, which bud from the adult. These arise in a string and suggest ova in higher animals.

The oval cilia are not in a wreath form, but line the gullet into which they are retracted when not in use.

The body wall contains fibrils similar to those found in the Vorticellidæ.

4. PROCYTOS VULGARIS; AN INORGANIC CELL

There is a question which often comes into the mind of students of cytology: "Where does the cell form come from? What was its origin and what relation does it bear to organic and inorganic nature?"

There is a growing number of students of natural phenomena who are diligently striving to show the relations of the organic world to the inorganic. To such the following study may be of interest.

A look at the photo (Plate XII., Fig. 5), which I have called *Procytos vulgaris,* shows a cell structure which bears a striking resemblance to many animal and plant tissues.

Here are to be found wholly inorganic formations which suggest cells with cell walls, nuclei, nucleoli, filaments and cyto-plasm bodies. These structures are purely inorganic and can be produced in the liquid form of any material, by observing certain conditions of temperature.

The material used in the present experiment is ozokerite, a refuse product from oil refineries in the form of wax. If this is melted and poured on a hot plate and allowed to cool slowly we get the effect pictured above.

The Giant's Causeway in Ireland is a somewhat similar production on a large scale, in an ancient outpoor of lava or melted rock.

The cells are centers of boiling by which heat is conducted from the base to the air, where the material is cooled and then moves downward again.

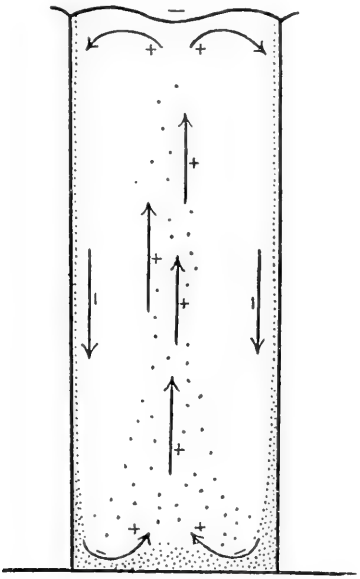


Diagram of Circulation in the Inorganic Cell

By consulting the diagram there will be seen two streams of fluid of opposite polarity. One stream of positive heat units goes upward in the center of the cell while the cooled units descend at the margin. Particles of various kind which may be in the fluid are carried along by the movements of the streams.

This boiling is easily seen in the fluid preparation as long as the material stays within a certain range of temperature.

The cells should in theory be correct hexagons, but some cells are more vigorous in action than others, resulting in the encroachment on the domain of other cells, thus deforming them.

The descending streams of cooled units deposit particles of various materials in the cell walls where they are cemented up by congelation into substantial walls.

The nucleus-like spots are caused by introducing bodies that do not readily mix with the wax—in this case air bubbles. These

become the center of a secondary activity. When the cooling has progressed far enough they collapse, forming the crater-like circles in the cells. The nuceoli are secondary eruptions of the air.

The markings within, which suggest cytoplasm, are caused by crystals of some fat which solidifies at a temperature different from the mass with which it is mixed.

Now, let us compare this structure with the similar characters of living cells and see wherein they both show dependence on natural conditions. First, we have here in both cases a definite enclsoure of certain activities. In both cases one form of this activity is heat; only within certain bounds of temperature are the activities of either possible. With the lowering of the temperature the components congeal, with the raising they disintegrate.

Second, the cells are rudely hexagonal in form. This follows from the association of semi-fluid bodies, their mutual pressure determining their shape.

Third, the formation in both cases, by precipitation, due to congelation or other process, of cell walls at the boundaries of the cell.

Fourth, a definite circulation of the cell contents which lasts as long as the components are in their requisite relations.

This may be plainly seen in plant cells where the protoplasm streams outward from the nuclei, bathing the cell wall on the side toward the source of heat and returning to the nuclei on the cooled wall.

Fifth, the formation of nuclei of substances of a nature different from that of the surrounding material, which results in definite secondary activities of a complicated kind.

Sixth, the precipitation and coagulation of various substances in the cytoplasm when they reach critical temperature points.

We thus see that there are structures and functions which occur in both the organic and inorganic world in quite similar ways. It is quite impossible to escape the conviction that forces that act in the one are also real causes in the other.

It is not pretended that the processes in this inorganic material are identical with those in the living cell, nor that temperature is the only factor in organic activity.

There are many types of fluid-formed crystals now known; some 300 or more. These are molecular arrangements of inorganic substances. Modern theories of crystal formation point to a fluid pre-crystal stage in which the components are adjusted into the relations in which they congeal.

When more definite studies of pre-crystal stages are to be had, we do not doubt that conditions similar to these we have described in this inorganic cell will be found.

Battle Creek, Mich. E. W. ROBERTS.

EXPLANATION OF PLATES

PLATE X—Rhizopods of Michigan

FIG. 1. *Arcella vulgaris;* constrictions of chromidial net into gametes.

FIG. 2. *Arcella vulgaris;* network matured into gametes.

FIG. 3. *Arcella vulgaris;* escaping gametes have left scars.

FIG. 4. *Arcella vulgaris;* asexual individual.

FIG. 5. *Clathrulina;* adult asexual form.

FIG. 6. *Clathrulina;* resting spore stage, also asexual.

PLATE XI—Nature of Olfactory Organs

FIG. 1. Antennæ of Black Syrphus Fly.

FIG. 2. Section of sensory pit in Sarcophaga.

FIG. 3. Section of palpus of *Pieris raphae.*

FIG. 4. Section of antenna of Honey Bee.

FIG. 5. Cross-section of olfactory pits on antenna of Vespa.

PLATE XII

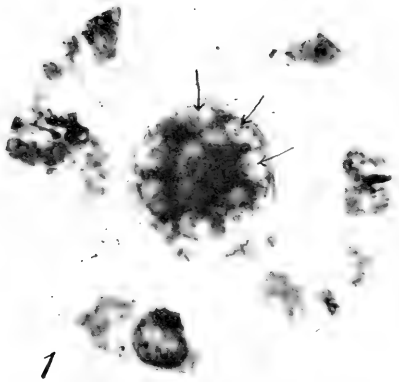
FIG. 1. *Vaginicola;* photograph of longitudinal section.

FIG. 2. *Vaginicola;* photograph of cross-section.

FIG. 3. Diagram of details in Fig. 1: A, sheath; B, aperture of same; C, the individual animal; D, nuclei (macro and micro); E, gametes; F, fibrils in ectoderm.

FIG. 4. Diagram of details in Fig. 2. Lettering as in Fig. 3.

FIG. 5. Photograph of ozokerite cooled in such a way as to suggest cells.



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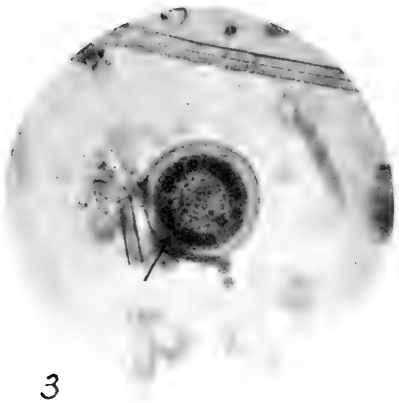

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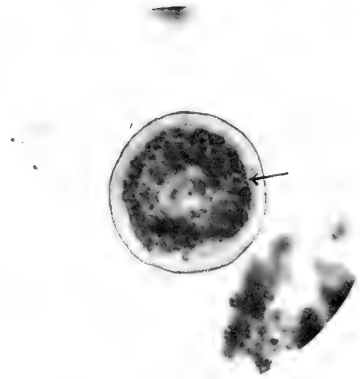

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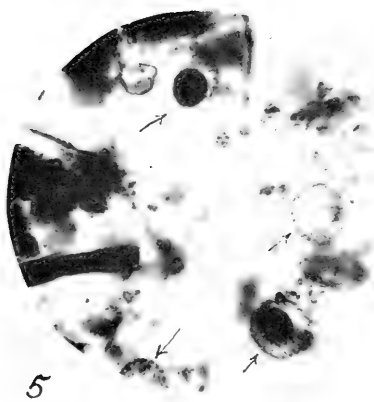

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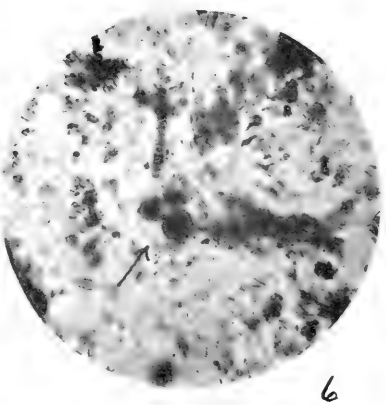

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PLATE X

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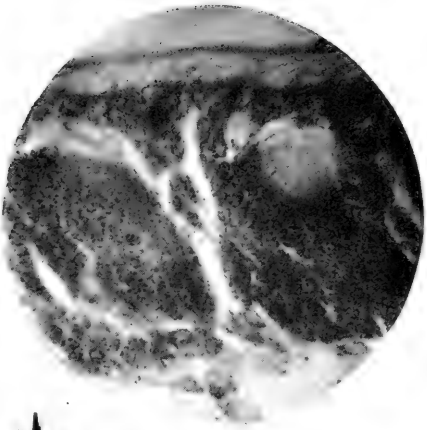

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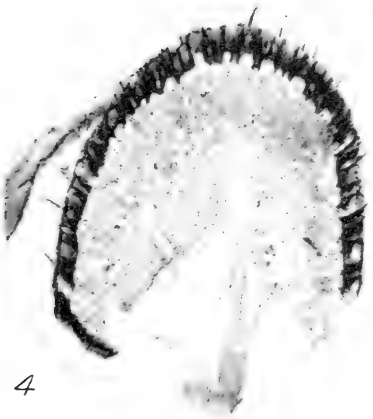

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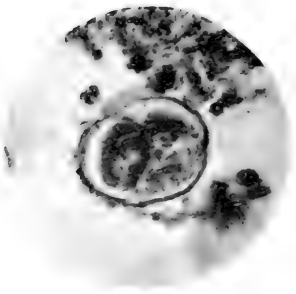
PLATE XI

1



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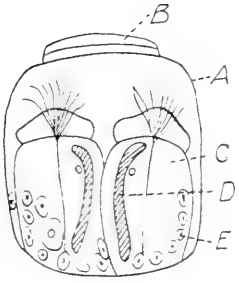

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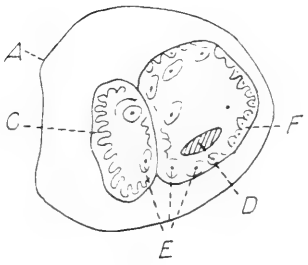

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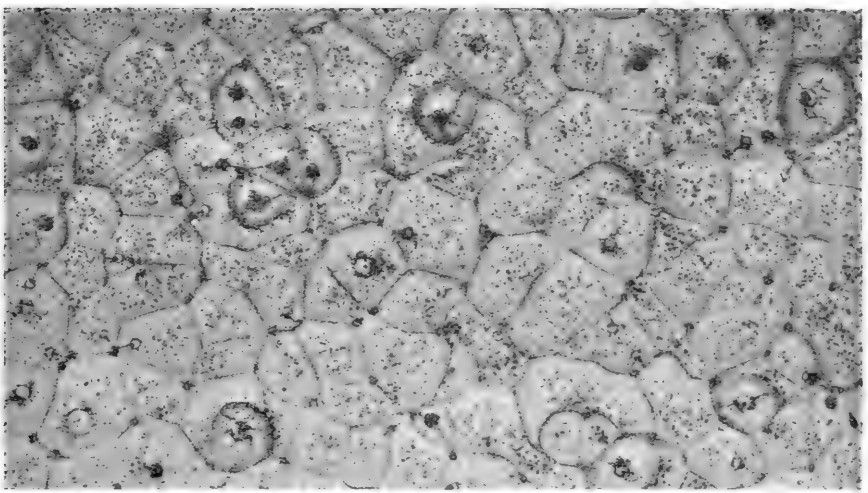

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PLATE XII

POLYEMBRYONY IN THE NINE-BANDED ARMADILLO.

Newman (Am. Nat., Sept. 1913) brings together many interesting facts concerning the biology of the Texas Armadillo, gathered from numerous papers which he has published previously. Since the paper is itself a summary, it is impossible here to summarize it.

Some of the most interesting facts relate to polyembryony. There are four embryos, which are enclosed in a common chorion. These four are always of the same sex. They are formed from a single egg fertilized by a single spermatozoon. The cleavage gives rise to an inner cell mass and blastodermic vesicle similar in all essenital respects to the rodents. It is in connection with mesoderm formation that the writer finds first two, and then four, buds within the general vesicle. The writer believes that this breaking up of embryonic activity, which might naturally be expected to continue as a unit. may be caused by lowered vitality, due to an egg parasite, coupled with an external pressure on the developing embryo exerted by a groove in the uterine wall. The latter tends though pressure to isolate the two halves of the embryo, and because of the low vitality it is not able to unify these bilateral growth activities.

Many interesting questions concerning heredity, sex-determination, and the like, offer themselves in connection with this very favorable material. For example, it is clear that these four embryos are much closer in kinship than is true of members of the same litter in mammals generally. Furthermore they occur in pairs which are mutually more alike than they are like the other pairs.

Each embryo ultimately develops its own independent connection with the mother, and they often differ signally in their nourishment, as shown by the rate of development. Since the quadruplets are invariably of the same sex, irrespective of their size, it is clear that the sex is determined before the isolation of the four centers of growth in the vesicle.

The female diploid number of chromosomes is 32, reducing to 16. In the male the diploid is 31, reducing to 15 and 16. This duplicates the conditions described in other vertebrates.

The same author (Jour. Exp. Zool., Aug., 1913) discusses in a much more extended way the many interesting questions of heredity suggested in the more general article.

PERSISTENCE OF BACILLUS ABORTIVUS IN TISSUES.

Fabyan (Jour. Med. Research, May, 1913) presents facts to show that *B. abortivus* has a quite prolonged life in the tissues of apparently healthy laboratory animals—as guinea pig, rabbit, mouse, rat, pigeon, etc. In one instance they were harbored without any external signs of ill effects for 67 weeks. Two additional conclusions seem warranted from the experiments: First, that there seems to be at least a slight temporary multiplication of the germs after inoculation; and, second, that the animals are not without the power slowly to destroy the bacilli.

The study is interesting as bearing on possible periods of endurance and latency of pathogenic bacteria after the disappearance of the symptoms of the disease.

PERSISTENCE OF TUBERCLE BACILLI IN CULTURES

Smith (Jour. Med. Res., May, 1913) tests the current view that tubercle bacilli lose their vitality in cultures in periods of 1 to 6 months. He found that cultures which completely ceased to multiply on the artificial media under wholly favorable conditions were still infectious to guinea-pigs for from 7-19 months. This was true both of human and bovine strains; though of the two types when reared side by side the bovine is the more resistant. It is true that the number of bacilli surviving in such cultures is very small. The series of biological facts is suggestive: Tubercle bacilli (bovine), which on removal from the diseased animal do not at first multiply on glycerine agar, may in time become partially saprophytized and grow luxuriantly on such culture media; gradually this culture medium fails to serve their purpose, and most of them die; as long as vitality lasts the fresh tissues of the guinea-pig furnish an adequate medium for their restoration.

CAMBIUM GROWTH IN AMERICAN LARCH

Knudson (Bul. Tor. Bot. Club, June, 1913) presents a study of the American larch in respect to place and time of beginning of

cambial activity, the relation of xylem and phloem formation, and the like. As the result of two years' studies he concludes, for this species, that the development of the phloem precedes that of the xylem; that the first increase in diameter of xylem begins a few meters below the apex; that the development of the xylem begins about a month later than the leaf formation, altho there seems, according to other investigation a diameter increase about the time the leaves appear. This, the author thinks, is due mainly to a swelling of the tissues, of the turgor type.

It is suggested that temperature of the soil, moisture of the air, the thickness and color of the bark, as well as other unknown factors may determine the place and date of diameter increase.

CELL-DIVISION IN THE SEX CELLS OF TAENIA

Harmon (J. of Morph., June, 1913) presents evidence that the division of the spermatogonial cells and the two spermatocyte divisions in Tænia are mitotic. In the ova mitosis is frequent and there is no evidence of amitosis in the oogonial division; the maturation divisions are mitotic, and mitotic divisions occur both in early and late cleavages. The author believes that there is no reason to believe that amitotic division occurs in this animal—contrary to the conclusions of earlier studies. She believes that the close contact of nuclei and other items that have been interpreted as meaning amitosis are due merely to special conditions of mitosis—as the nuclei dividing more rapidly than cytoplasm, shortness of cleavage spindle, swift reconstruction of nucleus after splitting of chromosomes, rapid growth of daughter nuclei, etc.

METAMORPHOSIS OF FILARIA LOA

Dr. Leiper (Lond. Sch. Trop. Med., Jan., 1913) telegraphs from Calabar that the Metamorphosis of *Filaria loa* has been proved to take place in the salivary glands of a fly belonging to the genus Clorysops.

DEMONSTRATION OF BROWNIAN MOVEMENT

Mr. Travis of the Queckett Club describes a satisfactory method of demonstrating striking Brownian movements. Rub a small amount of gamboge for a few moments on an ordinary microscope

slide. Place a drop or so of water where the gamboge has been rubbed. Gently push the edge of a cover glass up to the gamboge; with suitable illumination the whole field is seen in very brisk motion.

FRESH WATER DIATOMS AND THEIR PREPARATION

Groom (Eng. Mech., March, 21, 1913) invites the microscopist to the study of the Diatoms. He quotes: "Contemplation of the netted beauty of some small part of nature may bring man, as he grows older, the admiration of a vision of the whole," and thus advises: Go to a pond, collect a quantity of Pond weed. Wash this by shaking thoroughly in, say a wide-mouthed 2-pound jar nearly filled with water. Pick out all of the weeds possible, shaking to free them of the diatoms. Allow to settle for two hours and pour off all the water possible. Put the sediment into a saucer with a fair quantity of water and place it in a sunny window. Next morning take a fine piece of muslin big enough to cover the saucer; soak it, wring it out, place it over saucer; press it down so that it rests lightly on the surface of the sediment. After a time the free diatoms will make their way through the meshes of the muslin and discolor it. The diatoms are thus collected on the upper surface of the muslin free from the sandy debris. They can be mopped from the muslin into clear water with a camel's hair brush.

MOUNTING FRESH-WATER ALGAE

English Mechanic (Nov., 1912) makes the following suggestions for beginners. For unicellular algæ (diatoms, desmids, etc,). remove as much water as possible from them with a pipette, transfer to a watch glass of filtered rain water or clear water of the kind they live in. Carefully stir up the sediment, allow to settle, remove the water and the very surface of the sediment with a pipette. Repeat this process until a supply has been obtained freed from the sand and mud. Remove water and add a fluid made up of alcohol, 3 parts, water 2 parts, and glycerine 1 part. Stir the specimens well and leave it in an open watch-glass for 10 days or more until the alcohol and water are evaporated—*nearly* covering the vessel to keep out foreign dirt. Do not use heat to hasten evaporation. Mount in warm, not *hot,* glycerine jelly.

MOUNTING VOLVOX

English Mechanic (Feb. 14, 1913) offers the following method for preparing this interesting organism. If in sufficient quantity pour through a fine cloth funnel. After a couple of minutes place the cloth in tube or dish of 2½ per cent formol. Fix for about 5 minutes. Remove the muslin containing the material, which will now be a gelatinous mass of volvox and other small organisms that may have been present.

To remove volvox from muslin, place some 2½ formal in a slightly sloping white plate. Open out the muslin and place the volvox in contact with the fluid. A sable brush and a hand lens should be used to push each volvox off the cloth and up the inclined plate out of the formol. If there is much dirt pour off the old fluid, wipe the plate and replace with clean formol.

Transfer to ringed cell with pipette, and mount. Care is necessary to prevent drying out and the formation of air bubbles.

COUNTING LEUCOCYTES IN CEREBRO-SPINAL FLUID

Chauvet (Le Monde Med.) refers to the necessity of technical exactness in this process for diagnostic and other reasons. The small amount of the fluid available is a complicating fact. He describes at some length the two methods in use: Centrifuging, and Nageotte's Cell Method.

The centrifugation method involves centrifuging, the clotting of the cellular elements, dropping clot on slide, drying it in open air, fixing with absolute alcohol or ether, staining in aqueous eosin (1 per cent) or with hæmatoxylin, mounting in cedar oil. Under normal conditions one finds not more than 2 or 3 mono-nuclear cells on an average in a 1-12 immersion field. It would imply a pathological lymphocytosis if 7 or 8 lymphocytes were to be found in that space. It is quite clear that the method is open to such possible errors that enumeration by means of it must be uncertain in diagnostic value.

Nageotte's Cell Method involves the use of a cell of known dimensions. Its bottom is ruled into minute parallelograms. This cell is completely filled with cerebro-spinal fluid to which a minute amount of Unna's blue has been added for staining. The filled cell

is placed on the movable stage and allowed to rest for five minutes until the lymph cells settle. The cells in a few adjacent rectangles can be readily counted by means of Leitz No. 5 or 6 objective. The number per unit of volume can be computed from the known depth of the cell and the size of the parallelograms.

The latter method is much more exact and convenient.

TOXIC SECRETIONS OF INFUSORIA

Woodruff (Jour. Exp. Zool., May, 1913) reaches the conclusion that Parameciam and some of the hypotrichous protozoa excrete substances that are toxic to, and tend to inhibit the rate of reproduction in their own species. These products are specific in their action since their presence does not uniformly influence the rate in a species other than that producing it.

It is apparent that this factor is necessarily one of importance in determining the continuance of cultures and the succession of organisms in them.

A few pedigreed specimens of Paramecium were placed in culture media, which differed only in that one had contained a rich culture of paramecia for several days, another had contained a similar culture of hypotrichs, and another had no protozoa. All the media had the same bactrial flora.

RELATIONS OF CELL SIZE AND NUCLEAR SIZE IN OXYTRICHA

Woodruff (Jour. Exp. Zool., July, 1913) finds that there is great variation both in the actual size of nuclei and cells and in the size of these in relation to one another in all the periods of the life of the race. That is to say there is no absolute or relative size which is characteristic of any age. The average size of the nucleus, and of the cell itself is *smallest,* and the proportion of nuclear to cytoplasmic matter is *highest* during the period of greatest reproductive activity. The author believes that the mass relations of nucleus and cytoplasm are not the determining features of reproduction.

INFLUENCE OF MATING IN PARAMECIA

Jennings and Lashley (Jour. Exp. Zool., April and Aug., 1913) find that the conjugation of paramecia has a distinct influence upon

the character of the descendants of both conjugants. These two lines of offspring descended from a pair of conjugants are more alike, both in their rates of fission and in the length of their bodies. There is a correlation, as has been previously seen, in the body length of parents, owing to assortative mating. But the correlation between the offspring of parents that have mated is 48 per cent greater than that between the parents themselves, which shows inheritance in the offspring from both parents.

AMITOTIC DIVISION IN CILIATED CELLS

Jordan (Anat. Anzeig. XIII, 1913, p. 598) contributes to the study of the behavior of ciliated cells, a report of the epithelial cells in the epididymis of the white mouse. He finds that division here is exclusively amitotic. Not a single mitotic figure was seen; but all stages of direct nuclear division are found. The prevalence of amitotic division has been shown in the epididymis of other animals, in the ciliated cells of the trachea, and in the ciliated cells of the gills of the clam. Jordan believes that the loss of power of mitotic division in these ciliated cells is due to the fact that the centrosome, whose activity institutes indirect nuclear division, is used up in the formation of the basal granules from which cilia are developed. In a way the power of mitotic division is the price they pay for cilia.

SPERMATOGENESIS IN SILKWORMS

Yatsu (Annot. Zool. Japan., Vol. VIII., Pt. II., July, 1913) undertakes to find whether there are any chromosomal differences between the various races of silkworms that are correlated with the morphological differences. He studied in all some seventeen domestic varieties of Bombyx—Japanese, Corean, Chinese, Turkish and European. His results were negative; that is to say, he found no differences of shape, size or number in the chromosomes of the morphologically different races of domestic worms. The haploid number he finds to be 28; the unreduced number is therefore 56.

The wild silk worm, *Theophila mandriana,* however, has 27 as the haploid number. If therefore, as some writers think, the wild form is the ancestor of the domesticated races, the latter have

acquired two chromosomes (in the unreduced nucleus) in the course of domestication.

EDUCATION OF INFUSORIA IN INGESTION OF FOOD

Metalnikow (C. R. Soc. Biol., Paris, 1913, pp. 701-704) states that infusoria may be brought to use more selection in the taking of substances. By using substances only slightly injurious or even substances with no nutritive qualities, he found such substances would be taken indiscriminately at first; but after a period of hours or days they cease to take them in. Such substances, at first taken freely and later refused, were aluminium in emulsion, sudan red, phosphorus, sepia, and carmine. In some instances the presence of another substance would induce them to swallow particles which they had learned to refuse. For example, they would take a mixture of sepia and carmine when they refused carmine alone.

SPIROSTYLE IN SPERMATOZOA

Champy (C. R. Soc. Biol., Paris, 1913, pp. 663-4) makes a comparative study and an interpretation of the spiral, rod-like body found in many spermatozoa. He suggests axostyle and spirostyle as its name. He finds it in several amphibians; it has also been described in some reptiles, birds and mammals. He traces the development in amphibian from a simple axial rod in the nuclei of the spermatids to a twisted spiral one in the early stages of sperm formation, and finally to its partial or total disappearance in mature sperm. Its twisting in development involves both the nucleus and the cytsplasm, and thus may give a definite torsion to the whole spermatozoan. The result in the motion of the sperm is to produce a spiral course such as we see in many of the protozoa.

NERVE FIBRILS IN DENTINE

Contrary to the usual interpretation, Mummery (Proc. Roy Soc., Ser. B., 1912, p. 79) holds that the dentine of the teeth is innervated clear to its outer edge by nerve fibrils from the pulp cavity. There is a plexus over the outer surface of the pulp, and from this the neurofibrils, usually two to each tubule, enter the

dentine tubules and run their whole length to the point where the enamel or cement joins. This enables us better to understand the power of the dentist over us.

SUCCESSION IN FUNGI

Brown and Graff (Philip. Jour. Sci., VIII, Sec. C. I; 1913, p. 21) report studies on the succession of fungi growing on dung. This is a class of studies always of value to directors of laboratories, and more of such should be made. The authors' record that the moulds, as the *Mucors,* first appeared, followed by *Oospora.* These disappeared in about 10 days. Next appeared the sporophores of species of *Coprinus,* which persist for a long time. The authors believe the order of appearance is due to different periods of latency and rates of development of the spores of the species; and that the poor persistence of the early types were due to hurtful micro-organisms or to toxins formed in the dung about the fungi. Experiment showed that the *Mucors* were not short-lived on sterilized materials.

RUSTS AND THEIR HOST TISSUES

Tischler (Flora 104, 1911; Bot. Gaz., Aug., 1913) describes the relation between *Uromyces Pisi* and *Euphorbia Cyparissias,* its host in the æcidial stage. The rust winters in the buds of the subterranean shoots, and as these grow it tends to keep pace with them. If the parasite thrives the host is deformed in a characteristic way. The author investigated the following among other questions. Under what conditions do the shoots of the host outgrow, and escape as it were, the ill effects of the parasite? Along what routes do the hyphae of the rust run in keeping pace with the new growth? Just at what time in the cell history do the hyphæ change the cell so as to produce the deformed growths?

It was found that the shoots might grow away from the fungus by furnishing high temperature and other conditions which would force the growth of the host. Also when the rust approaches its fruiting stage the host may outgrow it. If kept in the dark so that æcidia do not form, the buds cannot grow away from the rust.

The hyphæ of the rust do not succeed in sending haustoria into the meristematic cells, and hence the deformation is not due to

effects at this point, whether at the tip or in the cambium. But as soon as the cells cease to be meristematic, or embryonic, and begin to form vacuoles the haustoria are formed and modification of the cells begins.

The hyphæ keep up with the growth of the shoots by following the trachæ, from which they penetrate the surrounding tissues.

PHYSIOLOGICAL EFFECTS OF BORDEAUX MIXTURE

It has been claimed that Bordeaux mixture, in addition to its fungicidal effects, augments the assimilative activity or plants on which it is sprayed. Ewart (Zeitschr. Pflanzenkrank. XXII, p. 257: Bot. Gaz., June, 1913) finds by experimenting with potatoes, radishes and beans that the yield was always decreased by covering the leaves with the mixture, and in proportion to the strength of the mixture. He also found that the sugar content of currants was increased by spraying the *fruit* with the mixture, and decreased by spraying the leaves alone.

HERMAPHRODITISM IN AMPHIOXUS

Goodrich (Anat. Anz., 1913, p. 318) describes an interesting abnormality in this animal. A male specimen with 25 testes on one side had one of the 25 gonads on the other side a perfectly developed ovary with numbers of large ova. All the 49 testes were perfect and full of sperm.

RESISTANCE IN HIBERNATING ANIMALS

Bertarelli (Centr. Bakt., 1te Abt. Orig. XVIII, 1913, p. 566) finds that marmots are not more resistent to rabies, anthrax, tetanus, and diphtheria during hibernation than at other times. Blanchard had previously reported these animals to have increased resistance, during hibernation, to cobra venom, diphtheria, tetanus, trypanosomes and trichina.

MICROSCOPIC MEASUREMENT BY CAMERA LUCIDA

Joly (Sci. Proc. Roy. Dub. Soc., XIII, 1913, p. 441) suggests a simple method for measuring microscopic objects by means of the camera-lucida. Draw two fine lines, diverging from a point, on a

piece of white paper. The angle of divergence will be determined by the size of the object to be masured. The image of the object to be measured is projected on the sheet of paper. The paper is moved until the object just fills the space between the lines, and a mark is made across the lines at this point.

A stage micrometer scale is then substituted for the object and is moved along the diverging lines until a number of the divisions exactly cover the space between the lines. This point is marked as before by a cross line. The distance from the intersection of the lines to each of the cross lines is measured, and one has two similar triangles from which a single proportion can be derived in which the size of the object is the one unknown quantity—diameter of object: micrometer divisions:: distance from intersection to object: distance from intersection to micrometer.

MICRO-RADIOGRAPHY

Goby (Comp. Rend. CLVI, pp. 686-8: Trans. in J. R. M. S., Aug., 1913) reports the application of the X-ray to making visible the internal structure of opaque microscopic objects. "It replaces the method of section cutting, which is often slow and costly, and always indirect and destructive of the object, by a method which, whilst rapid and preserving the object itself, reveals sufficient detail to make it only necessary to enlarge the minute radiogram directly obtained, in order to be able to study it with the naked eye with the same facility as an ordinary macro-radiogram."

The difficulty of doing this has arisen in getting the necessary clearness of detail by means of Röntgen rays. This is overcome by an ingenious contrivance which suppresses the secondary or superfluous rays, and insures that the incident rays shall be normal. For details of the apparatus the reader must refer to the citations above. Figures are given which are enlarged (x 19-25) reproductions of micro-radiograms of Foraminifera and of the limbs of a small three-toed lizard. The results are remarkable.

CIRCULATION BY CONVECTION CURRENTS IN LABORATORY AQUARIA

Gemmill (J. R. M. S., June, 1913) describes a simple method for getting a gentle circulation and æration in single or serial small

laboratory aquarium jars. It depends in principle upon a water current some degrees lower than that of the aquaria in the laboratory.

The author recommends tall beakers with about 9 inches of water in them. The current of colder water is carried through a U tube of glass, which is connected with the tap and the sink by rubber tubing. The U tube is of ½-inch tubing, and dips some 4½ inches into the beaker of water. This leaves an equal distance of water in the flask below the U tube.

The cool current flowing through the U tube cools the water in immediate contact with its surface. A downward convection current is thus caused in the middle of the jar. The water at the wall of the jar, exposed to the higher temperature of the laboratory will supply an upward convection current. Enough of the surface water is carried downward in the descending current to insure oxygenation of the whole volume.

For delicate floating larvæ, such as *Asterias,* the author shows that this method is much more satisfactory than streams of air bubbles. The danger of mechanical injury is eliminated, and it is possible to isolate the vessels so as to prevent infection even from the atmosphere. Manifestly a series of U tubes can be used so as to make the same stream serve a whole battery of vessels.

SIMPLE HISTOLOGICAL METHODS

Salkind (J. R. M. S., Aug., 1913, p. 426) has brought together some simplifications of histological methods:

1. *Sublimate fixation*—Instead of removing the salts of mercury by the usual method, the iodine treatment may be carried on during the removal of the paraffin by placing the mounted paraffin sections in xylol saturated with iodine. In order to do this, after fixing in Zenker's or Helly's fluid, the objects are placed in a solution containing 3 per cent potassium bichromate and 1 or 2 per cent hydrochloric acid. If acid solutions are not suitable, use the following instead: Water, 100 c.c.; corrosive sublimate, 4 grms.; potassium bichromate, 2.5 grms.; chloral hydrate, 4 grms.

2. *Aceton-Ether Method of Paraffin Embedding*—Remove tissue from water or weak alcohol and place in a fluid composed as

follows: Acetone, 2 parts; ether, 1 part; water, 1 part. Keep in this at least one hour for each millimeter of thickness of the tissue. Transfer to a mixture of equal parts of acetone and ether saturated with paraffin. Transfer to paraffin.

3. *Simultaneous Polychrome Stain*—Saturated watery toluid-in-blue with 3 per cent formol, 12 parts; alcohol, 90 per cent, 8 parts; acetone, 4 parts; saturated naphthol-yellow in 90 per cent alcohol, 2 parts; saturated erythrosin pur., in 90 per cent alcohol, 3 parts. Mix in above order. Add 5 to 10 parts of distilled water. Let stand. No precipitate should appear. The fluid should be a dark blue, with a violet shade in a few minutes.

4. *Adhesions of Sections to Slide*—When the paraffin sections are floating in warm water, add one drop of cedarwood oil. This spreads as a thin film over the surface of the water. Sections mounted direct from this fluid will adhere firmly.

REDUCING STOCK SOLUTIONS

Löwe (Zeits. wiss. Mikr., XXIX, p. 545) suggests a simple method for reducing concentrated stock solutions of reagents to the dilute form in which they are to be used. Pour into the graduate a quantity of the stock solution, whose cubic centimeters equal in number the *percentage strength* desired in the dilute solution. Add to this enough of the diluting fluid to make a total number of cubic centimeters equal to the percentage strength of the original stock solution. If, for example, one wishes to make a 2 per cent solution from a 15 per cent stock solution, put 2 c.c. of the stock solution into the graduate and then fill until it totals 15 c.c.

PARASITOLOGY; LABORATORY GUIDE

This laboratory manual for the study of parasites will be of great value to zoology teachers who are not themselves experts in parasitology. The exercises included in the book are based on courses in the University of California on Human Parasitology and Veterinary Parasitology, each of one half year.

The introduction deals briefly with the biology of parasitism. The body of the book is divided into three parts, as follows: I., Medical Etomology; II., Helminthology; and III., Life History Studies on Living Parasites.

Part I. opens with a brief discussion of insects and diseases. Exercises follow, among others, on the mouth parts of insects; the internal structure of insects; biting lice; sucking lice; bed bugs; mosquitos; buffalo gnats; horse flies; house flies; fleas; ticks; mites; venomous spiders; ameba; trypanosomes; malarial parasites.

Part II. includes exercises on the round worms, hookworms. lungworms, trichina, filariae; leeches; liver fluke and other trematodes, cestodes.

Part III. provides for the study of the life history of the common house fly, the mosquito, and the flea, and gives suggestions of general procedure in the investigation.

There are useful exercises on parasiticides and anthelmintics, and their value.

In most groups both morphological and systematic studies are outlined.

The book could have been made more valuable for the general zoologist without a great increase in its size, by the addition of a few devices for identification at least of some of the less commonly known parasites, with suggestions for finding, preparing, and displaying them. The exercises pre-suppose ready-made preparations, except in the three life-histories in Part III. The exercises do not make as much use of the suggestive question and the research spirit on the part of the student as the reviewer feels is wise; but rather follows the method of indicating what is to be found and expecting the student to verify and identify the findings.

A Laboratory Guide to the Study of Parasitology, by W. B. Herms, The Macmillan Company, New York. 72 pages. Price 80 cents net.

PREVENTION AND CONTROL OF DISEASE

This book is designed to bring the remarkable work of research students of recent years, in respect to the prevention and control of diseases, within reach of the general public. It is felt that such an increased audience which understands something of the steps necessary to control disease will advance the work in two ways. It will make the general public more sympathetic with the investigations that are necessary to get the facts, and more willing to support the legislators and the health officials who must apply them.

In style and content the treatise is admirably adapted to the needs of those for whom it is written—the intelligent general reader and the undergraduate student in college classes.

An enumeration of some of the principal chapter headings will enable the reader to appreciate its scope. Chapter I. is an introduction dealing briefly with some elementary biological matter. Succeeding chapters are Death-rate and Disease-prevention; Various Types of Disease and Hygienic Considerations; the Germ Theory of Disease and other Theories; The Life of Micro-organisms; Plant and Animal Parasites; Micro-organisms in Air, Water, and Food; Infection and the Spread of Disease; Disinfection and Disinfectants; Susceptibility and Resistance; Immunity; Specifics in the Treatment of Disease; Colds and Their Like; Filth Diseases, Typical and Special; Smallpox and Vaccination; Wound Infections; Diphtheria and Pneumonia; Contagious Diseases of Childhood; Tuberculosis, Its Manifestations and Causes, Its Prevention and Control, Its Cure; Yellow-fever and Malaria; Cancers; Diseases of the Second Half of Life.

The general order of discussion in each group of diseases is: (1) The general nature of the disease; (2) the history and geographical distribution; (3) cause and manner of infection; (4) prevention and control.

In our recent agitation against tuberculosis and typhoid we have been inclined to forget that there are scores of other less common or less fatal diseases, that are largely preventable, which diminish human efficiency very greatly. Without removing any of the necessary emphasis on these more important diseases this book will give the general reader a less hysterical or unbalanced attitude toward the whole question of preventable diseases.

The matter of the volume is presented in clear attractive style which will make it welcome for the purposes for which it was written.

Prevention and Control of Disease, by Frances Ramaley and Clay E. Giffin. 386 pages. For sale by the University Store, Boulder, Colorado. Price $3.00. Special rates where employed as a text book.

TRANSACTIONS

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The Society does not hold itself responsible for the opinions expressed by members in its published *Transactions* unless endorsed by special vote.

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NOTICE TO MEMBERS

Members are hereby notified that the regular annual meeting of the American Microscopical Society will occur in Atlanta, Georgia, at 3:30 p. m., on Wednesday, December 31st, in connection with the American Association for the Advancement of Science. The place of meeting will be announced in the official program of the A. A. A. S. The meeting of the Executive Committee will be held at Georgian Terrace at 12:30 noon on December 30th, at which time the committee members who are present will lunch together.

TRANSACTIONS
OF
American Microscopical Society
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REPORT OF THE SECRETARY AND EDITOR

T. W. Galloway

The issuance of this number closes the period for which the present Secretary was elected. It has not been the custom for secretaries of the American Microscopical Society to issue an address to its members thru the pages of the Transactions; nor is it the usage for editors of scientific magazines to do so. There are certain reasons however why it appears to the writer appropriate for him, in the combined capacity of Secretary and Editor, to bring before the Society in this form a statement of the work done during this triennium, and to indicate what seem to be the deductions fairly to be made as the result of the developments of the period.

This has been a time of transition for the Society. Historically, there was a long period in the early history of the Society when there was a successful annual meeting supported by a limited number of enthusiastic microscopists from the country at large and by a considerable number of actual microscopists and well-wishers worked up at or near the place of meeting.

With the inevitable extension of the use of the microscope in all institutions of learning and the specialization of the people using it, there came a period in which the annual meetings dwindled, and could scarcely be called successful from the point of view of even the most optimistic friend of the Society. Even where the attendance was fair, the cleavage of interest between the amateur worker and the professional work became so pronounced as to make the scientific program something of a trial to both.

When the present Secretary assumed the work it soon became apparent that a choice of emphasis must be made. On account of the great distances in our country, because of the diversity in the

specialization of our membership, and because of the great development of the special scientific societies for the promotion of particular realms of work it seemed wise frankly to give up hope of having successful programs of the American Microscopical Society, and to confine the annual meeting to such business routine as is absolutely essential to preserve the integrity of the corporation.

The necessary corollary of this elimination of the scientific meeting, which was formerly one of the chief forms of service rendered by the Society to these members who could attend, was to bring to all members such timely papers, on subjects suited to the general membership of the Society, as the income would allow. All the energy and funds put into holding a meeting were to be put into the publications.

To effect this it was decided to change the form of the Transactions from an annual to a quarterly issue. While the expense of such issue is greater, it was felt that the timeliness would more than compensate for this. It was felt furthermore that a general journal devoted to somewhat broad aspects of microscopic biology, published in the middle west would, for a period at least, serve a real end in science, and might increase the appeal of the Society to the new generation of investigators and teachers. It would furnish a new avenue of periodical publication, and might be made to meet the needs of such groups of biological workers as are least well supplied.

It was urged by some friends of the Society that the Quarterly Transactions undertake to fill some very special field,—as cytology —which is not at the present time occupied by any American publication. Such a course presents many elements of attractiveness. Partly because such narrow specialization would be a complete break with all the traditions of the Society and partly because the Secretary did not feel competent to pilot such a venture, it seemed wiser, however, merely to find a fairly permanent clientage in need of certain things and to undertake to supply this need.

With this task in mind and because of his own experience as a teacher of biology in small colleges, the Secretary was convinced that there would be the least departure demanded from the tradition of the Society to undertake to supply certain features that

would be of practical value to the teacher or student with inadequate journal facilities. Such teachers usually find it necessary to be reasonably familiar with a rather wide range of special interests, and yet do not have access to the publications necessary to secure this familiarity.

In pursuance of this idea it appeared that there are at least three types of contribution that would be of conspicuous value to general students. These are:

First—Notes, reviews, abstracts of such special articles as are most valuable from the point of view of the teacher. The purpose is not at all to make these abstracts cover the whole field of biology, but rather to indicate some main lines of progress and to furnish the teacher with illustrations of the progress. Arrangements are now being made to get the help of several biologists to make abstracts of the most suggestive work done in their respective fields.

Second—Occasional digests by experts of recent progress in some restricted departments. It was contemplated that these would represent the work of specialists who would bring to the general reader the discussion of the main conclusions and tendencies and prospects within such fields. Several such have appeared. Others are in preparation.

Third—It was felt that synopses of some of the more important groups of microscopic and near-microscopic plants and animals, would be of great value to teachers. The thought again is not scientific completeness; but such a treatment of the species more likely to be met by a teacher or his students, together with keys, figures, and descriptions, as would enable identification by the student. It is a fact that we are beginning to recognize that our schools and colleges are neglecting to teach the students to identify and name at least a few of the forms they meet in their work. It is important that every biologist, no matter how narrowly he is specializing, should have some mastery over the classification of the more common animals and plants. From the point of view of the general teacher of biology there is most important pedagogical value in a certain amount of systematic work. These simple descriptions, keys, and figures of the more common species of microscopic organisms are designed to aid the general student and teacher, rather

than the specialist in the department. Quite a number of these have already appeared, as follows: Aquatic Oligochetes, Melanconiales, Rusts, Black Moulds, Powdery Mildews, and Cephaline Gregarines.

Others are arranged for and will appear from time to time until all the more common American forms have been touched upon. The Editor desires to express his appreciation of the help of the scientists who are consenting to do this task. Their prompt and cordial response convinces him that they believe the enterprise worthy.

It has been the purpose to maintain the space given to research articles over as wide a field of microscopic biology as conditions will allow. The flow of manuscripts has not been sufficient to require or enable the editor to have any plan other than to produce an issue of a reasonable size. This has meant that thus far those writers who have availed themselves of our pages have had very prompt publication. As the permanency of the Quarterly becomes manifest this supply will doubtless increase, with a corresponding delay in publication.

By vote of the Executive Committee the Spencer-Tolles Fund now becomes operative in encouraging and aiding investigators. The details of this arrangement may be had by application to Dr. H. B. Ward, Urbana, Ill., who is Chairman of the Committee having the awarding of this grant in hand. Results of investigation conducted under this grant will be published in the Transactions and will add to the value of the journal to members.

During these three years we may fairly say that the Society has prospered in respect to finances and in membership. In the latest list available to the Secretary when he took up the work, there were 226 names of members, and 33 of subscribers. There have been added in these three years 188 members and 36 subscribers. This old list with which we started had not been revised for some years, and thru death and resignations the original list has lost 115 names. Some of these names have been carried for these three years on the rolls with the hope that the members might renew their standing. Some have done so. This year about 65 of the old members' names are finally dropped from the list. During this year 45 members and 25 subscribers have been added. As this

is written we are printing a list of 293 members and of 68 subscribers—a total of 361. This list is almost absolutely a net list of members who are promptly keeping alive their membership. One more year of growth such as we have been having will place the membership at 400. This number will give the Society complete self support and enable the issue each quarter of a magazine of 80 to 100 pages of scientific material.

The Secretary would also call the attention of the Society to the gradual change in the character of the membership. We have lost the memberships, formerly numerous, of amateurs and well wishers brought into the Society thru the special efforts of the members living in and near a place of meeting. Most such members were transient; but among them were many amateur microscopists who meant very much to the life of the Society. This type of member we have not found a way to enlist as formerly. Our great gain has been among teachers. These have come in, one by one, on the recommendation of other teachers. Without doubt they will give us a more stable membership than was true formerly. While we have many physicians as members we have not been able to get hold of physicians thru our physician members as we have in the case of the teachers. This is doubtless due in part to the excellent character of some of the publications now available to physicians in the realm of medico-biological research.

The Secretary feels that the Society owes something still to amateur microscopists in America. Without forgetting any of the difficulties in the way, it would seem possible to conduct a department in which the matters most needed by isolated and incompletely trained students might be developed and dwelt upon. The various methods, devices, short cuts, and so forth, in connection with the discovery, collection, culture, preservation, mounting, and study of microscopic materials might well be brought out. Possibly a brief department of questions and answers might be established for amateur workers. The Secretary has been seeking some one to edit such a department, but as yet without success.

In conclusion, the writer wishes to renew a suggestion made last year in connection with the giving up of the annual scientific program. If successful meetings of general microscopic workers

are to be held, it must be under the auspices of societies of limited area and not by a national body. "It may be pertinent to suggest that, in the opinion of the Secretary, the Microscopical Societies of more local character should be able to carry on successful meetings. These may be state or city societies. There is no reason why really live, valuable meetings for practical discussions and demonstrations cannot be had under these circumstances. The number of people who use the microscope and are interested in its application is greatly increased. There are more indeed in a single city than were found in the whole nation when this society was organized. The A. M. S. stands ready to serve such local societies in any way possible. Indeed it seems as tho an effective division of labor would be: (1) the national society to furnish a magazine of microscopy and microscopic research; and (2) state and city societies to furnish the personal contacts and stimulus thru meetings. Some such broad affiliation of national and local societies ought to be possible and mutually supportive."

SUMMARIES IN MICRO-BIOLOGY

For some months the Secretary has been seeking to secure for this Journal and its Department of Summaries, a series of papers from biologists dealing with the chief groups of microscopic plants and animals. It has not been the purpose to present a complete survey of any of the groups. The wish has been rather to bring together in one article a statement of the following things:—general biology, the method of finding, the methods of capture and of keeping alive and cultivating in the laboratory; how best to study; the general technic; the most accessible literature; and a brief outline of the classification, with keys for the identification of at least the more representative genera and species of the micro-organisms likely to be found by the beginning students in the United States.

It has been felt that the getting together of such data as this, while not a contribution to science, would be a contribution especially to isolated workers and to teachers and students in the high schools and smaller colleges.

Papers have already appeared treating the aquatic Oligochetes, the Melanconiales, the Rusts, and Black Moulds. The following is the fifth paper of the series. It is proposed to have such synopses from time to time until the more common American species of such groups as the following have been covered: The Blue-green Algae, Conjugating Algae, Diatoms, other Green Algae, Downy Mildews, Yeasts, Hyphomycetes, Smuts, Rhizopods, Infusoria, Turbellaria, Bryozoa, Water Mites, Entomostraca, etc.—[Editor.]

THE POWDERY MILDEWS—ERYSIPHACEÆ

By George M. Reed

Introduction. The Erysiphaceæ constitute a well defined group of the Ascomycetes. Various common names are applied to these fungi, as mildew, powdery mildew, white mildew, blight. They have long been interesting forms for study, partly on account of the microscopical interest in observing the fruiting bodies with their characteristic and frequently ornate appendages, but more especially on account of their parasitic nature, in many cases being of considerable economic importance due to the injury caused to various seed plants.

The powdery mildews are obligate parasites, attacking various Angiosperms. In fact these parasites are mainly limited to the Dicotyledons, only one species being reported as common upon Monocotyledons—*Erysiphe graminis* on members of the grass family.

The group is characterized by the possession of two distinct fruiting stages. One, the conidial stage, develops during the summer and results in the formation of a very large number of white,

more or less ellipsoidal spores which are easily distributed by air currents. This stage has been referred to a distinct genus, *Oidium*, belonging to the Fungi Imperfecti. It is now described as the Oidial, or better still, the conidial stage. Later in the season the ascus stage of the fungus is produced. The asci, one or more, are borne within the fruiting bodies or ascocarps. The latter are small, more or less globular, dark brown or black structures without differentiated openings for the escape of the asci or ascospores. These ascocarps, or perithecia, are provided with peculiar appendages which are outgrowths of the outer layer of cells of the perithecial wall. They are sometimes ornately branched and their characteristics are of considerable value in classification. The asci are sac-like structures, more or less oval in shape, and at maturity contain two to eight ascospores depending upon the species. In general the conidial stage serves to spread the fungus rapidly and widely during the growing period of the host while the ascocarp stage serves to tide the fungus over the winter season.

Mycelium and Conidial Stage. With few exceptions the mycelium of the powdery mildews is external to the host tissues. It generally develops on either the upper or lower surfaces of the leaves, but frequently is found on the stems, flowers and fruits. The mycelium is generally hyaline, well developed and much branched and the hyphae which compose it are septate. Thus it is composed of many cells, each cell containing regularly one nucleus.

At numerous places on the mycelium a special hypha grows towards the host tissue, penetrates a cell of the host, and forms a haustorium. In many cases, these haustoria arise from a flattened expansion, called an appressorium, of the superficial mycelium. The haustoria function as absorbing organs and obtain the necessary materials for the mycelium from the host protoplast.

Generally these haustoria are confined to the epidermal cells. In a few cases they are formed in the deeper lying cells. For example, in *Uncinula salicis,* according to Smith (62), some hyphæ from the surface mycelium grow through the epidermal cells and form the haustorial expansions in the cells of the mesophyll tissue. (Pl. XIII, Fig. 2). Even in this mildew, however, most of the haustoria develop in the epidermal cells. In many cases, notably the

grass mildew, several of these absorbing organs may be found in a single host cell.

Smith (62) has quite fully described the haustoria of the Erysiphaceæ and their relation to the host cells. In most cases they are more or less globular swellings at the ends of the special penetrating branches (Pl. XIII, Figs. 1, 2). In the grass mildew, *Erysiphe graminis,* the haustoria seem to be highly specialized structures (Pl. XIII, Fig. 3). They consist of an ellipsoidal central portion with long finger-like processes at one or both ends. They would appear to be efficient absorbing organs and may be correlated with the vigorous development of mycelium and abundant production of conidia characteristic of this mildew. The haustoria of *E. galeopsidis* are also somewhat lobed. In fact the lobing of the haustoria of this species is the principal basis for separating it from *E. cichoracearum.*

The haustoria of all the mildews regularly contain a single nucleus; very rarely are two nuclei found in one haustorium.

As already indicated the mycelium of some mildews, in part at least, is endophytic. The mycelium of the genus Phyllactinia grows in the intercellular spaces of the mesophyll of the host leaves. The haustoria develop as side branches from the intercellular mycelium and penetrate the various host cells in the interior of the leaf.

Salmon (59) has described *Erysiphe taurica* as being even more endophytic in its habit than Phyllactinia. The mycelium is at first wholly endophytic; from this arise conidiophores which pass through the stomata to the exterior. The perithecia are developed on a superficial mycelium which originates from that in the interior of the leaf. Globular haustoria are found in the mesophyll cells of the host. Salmon has recently separated this species, on the basis of these characters, and placed it in a distinct genus—Oidiopsis.

As the mycelium develops special branches arise which grow away from the surface of the leaf. These hyphae form the conidiophores (Pl. XIII, Fig. 4), one of the fruiting stages of the fungus. At the end of each conidiophore a more or less ellipsoidal conidium is cut off. The hypha elongates again and a second conidium is cut off. This process of basipetal abstriction continues, finally resulting in the formation of a chain-like row of oval conidia, the oldest being at the apical end. These easily separate as they mature

and are readily distributed by air currents. The young cell which forms the conidiophore contains a single nucleus. Nuclear division precedes the cell division and thus each conidium comes to have a single nucleus.

The conidia germinate readily in water or moist air by pushing out one or more germ tubes. (Pl. XIII, Fig. 5). Unless applied to the proper host, however, but little growth occurs. If the conidia are placed on the proper host, mycelia with their haustoria are quickly developed which soon give rise to other crops of conidia. In the grass mildew 48-72 hours are sufficient for this cycle of development. Consequently during a single season a succession of crops of conidia may be formed and many millions of spores may be produced.

Development of the Perithecium. Although many students of the mildews had examined carefully the structure of the mature perithecium and had worked out systems of classification based upon its characteristics, De Bary (5) in 1863, was the first to adequately trace the origin of this structure. He studied the development of the perithecium of *Sphaerotheca castagnei* on Taraxacum. De Bary (6) later (1871) studied other forms and found their development essentially similar to that of *Sphaerotheca*.

De Bary describes the ascocarp or perithecium as arising at the point of contact or crossing of two branches of the mycelium. These branches push out protuberances at the same time which rise erect from the epidermis of the host. They are soon cut off by cross walls and the one from the lower hypha grows and takes the form of an elongated ellipsoidal cell. This is the archicarp or oogonium. The other branch, the antheridial branch, remains cylindrical and is closely applied to the oogonium, its upper end bending over and covering the apex of the latter. A cross wall cuts off a short nearly isodiametric cell, the antheridium, which is borne on the basal cell or stalk. The oogonium now develops into the sporocarp, usually being divided into two cells, the upper one forming the solitary ascus of this mildew while the other remains as a stalk cell to the ascus. The ascus subsequently produces eight ascospores. As the young ascus develops the envelope apparatus is formed by the outgrowth of seven to nine tubular hyphæ from the base of the oogonium and antheridium. These hyphae elongate, remaining in close contact

with each other and also with the oogonium and antheridium, finally meeting above the apex of the antheridium. Each hypha then divides by one or two transverse walls and the young sporocarp is surrounded by a single layer of cells. From the inner surfaces of these hyphae secondary branches arise which ramify and develop into a dense parenchyma-like weft formed of two or more layers of cells. From the outer layer of cells, those first formed, the appendages arise. The walls of these outer cells also thicken and assume a dark brown color.

In *Erysiphe* the main difference lies in the fact that the archicarp or oogonium grows into a curved tube and divides by transverse walls into a row of several cells. From these cells a number of club-shaped, erect asci are formed by each cell growing out into an ascus or putting out a few short branches which finally terminate in asci.

Although De Bary maintained that the perithecium originated as the result of a fusion of sex cells he was unable to determine the actual fusion of the protoplasts of the oogonium and antheridium. Harper (28, 29, 30), using modern cytological methods, has been able to verify De Bary's conclusion and has added many additional facts to the history of the development of the perithecium and the following account is based on his studies of Sphaerotheca, Erysiphe and Phyllactinia.

Both antheridium and oogonium arise as side branches of neighboring hyphae. The development of the oogonium generally preceeds that of the antheridium and it soon forms a short oval branch which can easily be distinguished from vegetative branches by being vertical to the leaf surface and also by containing denser protoplasm. After the oogonial branch has elongated until it is two to three times as high as wide, with a transverse diameter twice that of a vegetative hypha, it is separated from the latter by a cross wall. (Pl. XIV, Fig. 9). The oogonium contains a single nucleus which is hardly distinguishable from that of a vegetative cell. During this process the young antheridial branch bends up and grows close to the side of the young oogonium. After a time a cross wall is formed cutting off a single nucleated cell. After the complete formation of the oogonium the antheridial branch elongates and its nucleus divides (Pl. XIV, Fig. 10), followed by cell division which cuts off a

small terminal antheridium and a stalk cell (Pl. XIV, Figs. 11, 12). The antheridium is carried upward by growth, becomes closely appressed to the oogonium, and appears as a cap on the latter. Next the cell wall between the oogonium and antheridium is dissolved and the antheridial nucleus migrates through the opening and approaches the egg nucleus which lies near the center of the oogonium (Pl. XIV, Fig. 13). The nuclei now fuse and soon the opening between the antheridium and oogonium is closed (Pl. XIV, Fig. 14).

At the same time with the entrance of the male nucleus into the oogonium the development of the perithecial wall begins (Pl. XIV, Figs. 15-20). Hyphæ arise at the base of the oogonium and grow up around the antheridium and oogonium. These become multi-cellular by nuclear and cell division. The antheridium relaxes and collapses but persists among the wall cells for some time. Next, due to the enlargement of the stalk of the oogonium, the first series of wall cells are bent out and other hyphae grow up inside them and, by branching and dividing, form a sphere of cells about the oogonium. The wall of the perithecium then contains several layers of cells, the outer for protection, the inner for nourishment. From the former the appendages arise when the perithecium is about half grown (Pl. XIII, Fig. 8). These soon become thick walled and lose their protoplasmic contents on the further ripening of the perithecium.

The fusion of the two nuclei in the oogonium takes place before the completion of the first wall layer. As further development proceeds, the oogonium grows into the ascogonium. The fusion nucleus in the oogonium first divides, following by cell division (Pl. XIV, Fig. 17); the lower cell of these two develops no further. The nucleus of the upper cell again divides and this is followed by cell division; this process is repeated until a series of five to six cells is formed (Pl. XIV, Fig. 19). Each of these cells has regularly one nucleus except the next to the last which invariably has two. This penultimate cell develops into the ascus (Pl. XIV, Fig. 20).

In the early stages the development of the mildews with several asci is similar to that of Sphaerotheca. Harper (29, 30) has carefully traced the development of sex organs and established the nuclear fusion in the young oogonium of both Erysiphe and Phyllactinia.

The oogonium, after the fusion of the antheridial and oogonial nuclei, develops into the ascogonium (Pl. XIII, Fig. 6). This is accomplished by the elongation of the oogonium which becomes curved in a very irregular fashion. Nuclear division occurs but this is not followed at once by cell division. Instead further nuclear divisons occur. Soon, however, cell division takes place and there is formed a row of three to five cells. The end cell of the fully developed ascogonium regularly contains one nucleus while the next to the last or penultimate cell always contains more than one nucleus.

Following the formation of the ascogonium, the ascogenous hyphae arise as lateral branches of the former (Pl. XIII, Figs. 6, 7). Most, if not all, of these hyphae arise from the penultimate cell. The number of cells in each hypha varies but one cell in each becomes an ascus. These cells always contain two nuclei while the other cells of ascogonium and ascogenous hyphae are almost without exception uninucleated.

During these processes the perithecial wall is formed by the upgrowth of hyphae from the stalks of both antheridium and oogonium. These, by continued division and branching, form finally the many celled wall of the perithecium (Pl. XIII, Fig. 8). When the perithecial wall is fully differentiated the further development of the asci begins.

As already noted each young ascus always contains two nuclei (Pl. XIV, Figs. 19, 21). Harper (30) has traced with exceptional completeness the nuclear phenomena which occur in the further development of the asci (Pl. XIV, Figs. 21-24, Pl. XV, Figs. 25-33). The asci rapidly increase in size and consist of an upper enlarged portion, in which the nuclei lie, and a lower stalk-like portion.

When the ascus has attained about half of its mature size the two nuclei fuse to form the primary ascus nucleus. (Pl. XIV, Figs. 22-24). The union of the two resting nuclei results in the formation of a single spherical nucleus which increases in size with the further growth of the ascus (Pl. XV, Fig. 25). This primary ascus nucleus next undergoes division resulting in the formation of two nuclei; each of these divide giving rise to four which in turn divide forming eight nuclei in the ascus (Pl. XV, Figs. 26-30). This triple division of the primary ascus nucleus is characteristic not only of the

mildews but of by far the larger number of other Ascomycetes as well.

During all the nuclear processes from the first development of the young oogonium Harper has been able to demonstrate the occurrence of a central body and to follow its behavior. This central body is located on the nuclear membrane. "It constitutes throughout a point of attachment for the elements of the nucleus, and in all the various modifications which it and they undergo in the processes of division and fusion this relation is maintained in the most definite fashion. The central body by its position determines in an important sense a definite polar organization on the part of the chromatin, and thus of the nucleus as a whole." "In every stage the chromatin is definitely attached to either one or two central bodies on the periphery of the nucleus. The nucleus is hence strictly unipolar throughout its so-called resting stages, becoming bipolar by division of the center for the formation of the two daughter nuclei." Harper has given a continuous account "of the existence of the central body and the maintainance of its connection with the material of the chromosomes through two nuclear fusions in the oogonium and in the young ascus, through a series of divisions in the ascogenous hyphae, and the triple division in the ascus, and finally through the formation of the ascospores by free cell formation." "The central bodies are thus seen to be permanent structures of the cell during both the dividing and resting stages of nuclear development."

During the process of all three nuclear divisions there is a well developed system of astral rays which extend from the central body into the cytoplasm. This polar aster persists after the third division and functions in the process of spore formation.

In Phyllactinia regularly only two ascospores are formed, each with a single nucleus. The other six nuclei formed in the triple division of the primary ascus nucleus are regarded as supernumerary nuclei which soon disintegrate in the cytoplasm. In some mildews, however, as in Sphaerotheca, all eight nuclei function and the mature ascus contains eight ascospores. In the different mildews the number of ascospores varies from two to eight.

Harper has described ascospore formation as a process of "free cell formation." Following the completion of the third nuclear division, a beak is developed on the functional nuclei which are usually more or less pear-shaped.

The central body is located at the apex of the beak. In general the beaked nucleus and aster lie free in the cytoplasm but sometimes lie quite close to the ascus wall. The astral rays are folded over to form the plasma membrane of the spore. (Pl. XV, Figs. 31, 32). "The rays become elongated during the process by growth which apparently proceeds from the central body outward, and at the same time they fold over and combine side by side to form a continuous broad, umbrella-shaped membrane. Sometimes the rays on one side seem to be in advance of those on the other in the process of enclosing the spore mass. If, in folding over and elongating, the rays of one center come in contact with those of another, they tend to fuse, at least temporarily. Later, however, they must separate again, since one almost never finds spores with two nuclei." "The broad umbrella-shaped membrane gradually closes in to form, by further marginal growth, the ellipsoidal plasma membrane of the spore. The whole spore body is cut out of the previously undifferentiated cytoplasm of the ascus by the formation of a new plasma membrane derived from the fibers of the polar aster and without the deposition of a cellulose wall."

Following the enclosure of the spore plasm by the new plasma membrane, the central body breaks away from the membrane, the nucleus regains its spherical or oval shape, with the central body lying on the surface of the nuclear membrane. Finally a wall is formed about the spores and the development of the perithecium with its ascospores is complete (Pl. XV, Fig. 33) and there follows the resting condition.

In the formation of the ascospores only a part of the cytoplasm is used up. The delimitation of the spores leaves a considerable portion of unused material. The spores thus are imbedded in the remaining part of the ascus cytoplasm. This material is called epiplasm or periplasm and its presence is a constant feature in the ascus of the Ascomycetes.

In at least two species of Erysiphe—*E. graminis* and *E. galeopsidis*—spore formation does not take place on the living host. When mature perithecia of these forms are found an examination will show the absence of the ascospores. Instead these are formed the following spring. To just what stage the nuclear phenomena proceed in the fall in these forms has not been worked out.

The ascospores escape from the perithecium in the spring. Galloway (25) states that the perithecium may suddenly burst and forcibly eject the asci. The cells of the inner wall of the perithecium, which retain their protoplasmic contents, may produce a substance capable of swelling in water and so cause the rupture of the perithecium as suggested by Harper.

The ascospores, when placed in a damp atmosphere or in water, germinate by the formation of germ tubes. If the ascospores are sown on the epidermis of a suitable host the germ tube penetrates and forms a haustorium in the host cell. The superficial mycelium also develops from this tube and, by growth and branching, soon spreads over a considerable area of host surface, giving use to numerous conidiophores.

On some hosts of the mildews perithecia are rarely formed. One noted illustration of this is the mildew on the cultivated grape in Europe. Berkeley (7) in 1847 described the conidial stage of this fungus as *Oidium Tuckeri* and, although this mildew was recognized as a serious disease, the perithecia were not observed until 1893 when Couderc (15) found these fruiting bodies and determined finally the identity of this mildew with the American *Uncinula necator*. The perithecia are quite common on grapes in this country.

In 1907, 1908 and 1909 a serious disease of various oaks in Europe, caused by a mildew, was observed by a large number of workers. The conidial stage was very common and quite destructive to the foliage of young oaks. While perithecia have since been found, they are of rare occurrence on these hosts in Europe.

It is well known that the conidial stage of *Erysiphe graminis* is very common on blue grass and other grasses but perithecia are quite infrequent. In the vicinity of Columbia *Evonymus atropurpureus* is severely attacked by a mildew but, while a large number of plants have been carefully examined by the writer, the perithecia

have not been found. Various species of Xanthium are also attacked by the conidial stage but perithecia are rarely produced.

As already noted characteristic appendages are found on the mature perithecia of the powdery mildews. These are outgrowths of the outer layer of cells of the perithecial wall. They develop from different parts of the wall in different species and show characteristic differences in their form. Their function is uncertain. In many cases, perhaps all, they serve to set the perithecium free from the surface of the leaf. In Phyllactinia for example, Neger (40) has observed the bending down of the appendages and their straightening up as a result of the alternately moistening and drying of the perithecia. In fact, in the case of the Phyllactinia, it is quite usual to find the perithecium in the mature condition turned over on the surface of the leaf so that they rarely are found in the normal position.

In addition to the characteristic appendages which are found in all the powdery mildews, certain penicillate cells develop upon the apical portions of the perithecium of Phyllactinia. These arise as an outgrowth of the cells of the outer wall of the perithecium, then grow up more or less vertically, branching repeatedly. After they have attained their full size the walls begin to swell and become gelatinous. They fuse together laterally and form a slimy mass crowning the perithecium. They serve to attach the perithecia in an inverted position to various objects, more commonly to the living epidermis of the host after the perithecia have been loosened from their place of development by the hygroscopic movements of the appendages. The perithecia may fall upon *Fomes,* as has been recorded, and be re-attached by these penicillate cells. Perhaps the unusual host distribution of this species may be, in part at least, explained by the accidental re-attachment of the perithecia.

There are several questions of great importance raised in connection with the facts of cytological study of the mildews. One question is that of the significance of the double nuclear fusion which occurs in the life history of these plants. One nuclear fusion occurs in the oogonium, when the nucleus from the antheridium migrates through the opening in the cell wall and fuses with the

egg nucleus. The second fusion occurs in the young ascus, this nuclear fusion resulting in the formation of the primary ascus nucleus.

Some investigators of this group deny that there is any fusion of nuclei in the oogonium and that the nuclear fusion which occurs in the ascus is the real fertilization process in these forms. The ascus, by these workers, is interpreted as an egg. Harper, however, has given very convincing evidence of the sexual nature of the hyphæ first described by De Bary as oogonium and antheridium and leaves no doubt as to the nuclear fusion in the oogonium. His work has also been confirmed by Blackman and Fraser (8) although denied by Dangeard (16) and more recently by Winge (72). If the nuclear fusion in the oogonium is a sexual process, as seems certain, then the subsequent nuclear fusion in the ascus cannot be considered a sexual process and the ascus cannot be interpreted as an egg.

Harper (30) has attempted to explain this second fusion on the basis of the nucleo-cytoplasmic relation. He believes that this fusion is "correlated in some way with the vegetative development of the relatively gigantic size of the ascus as compared with other cells of the fungus." Large cells in general have large or numerous nuclei and small cells have small or few nuclei. Nuclear and cytoplasmic masses are in equilibrium when there is a certain proportion between them. "Any increase in the mass of either tends toward producing a corresponding increase in the other; a reduction in one necessitates a reduction in the other, in order that the nucleo-cytoplasmic equilibrium may be maintained."

"The ascus is to be developed as a relatively large cell to serve as a storehouse, with an abundant supply of material for the formation of ascospores; and in order that the nucleo-cytoplasmic equilibrium may be maintained, it must be provided with an excess of nuclear material as compared with the other cells of the ascogenous hyphae and the ascogonium. There are several stages in this differentiation of the ascus as to its nuclear content. It is binucleated from the first, while the other cells mentioned are uninucleated; and, further, its two nuclei fuse with the union of all their corresponding parts to form a single larger nucleus, which in turn grows with the further growth of the ascus."

"In the process of spore formation we have again a most striking example of the controlling influence of the so-called nucleo-cytoplasmic relation. The nucleus of the ascus divides to form two daughter nuclei, and these in turn divide successively to form eight nuclei; but in thus passing from the uninucleated to the multinucleated condition the nucleo-cytoplasmic equilibrium is maintained. The two daughter nuclei are proportionally smaller than the mother nucleus, and the four and eight nuclei in the end bear approximately the same relation to their cytoplasmic masses as did the primary nucleus of the ascus to the cytoplasm of the entire ascus. The two nuclei which become the centers for the formation of spores grow to a somewhat larger size than the remaining six, and accordingly the mass of cytoplasm included in the two spores is more than one-fourth of that of the entire ascus."

Another fact to be explained is the universal triple division which occurs in the ascus of the powdery mildews as well as in that of all the higher Ascomycetes. The fusion nucleus regularly divides three times in rapid succession forming eight nuclei. It is very common for eight ascospores to be formed, although frequently the number is less, due to the non-functioning of one or more.

It is well known that in all the higher plants there is a double division of the spore mother cell during which the number of chromosomes is reduced. The doubling of the chromosomes occurs upon the fusion of the nuclei of the two sex cells. Since this double division is necessitated by the single fusion, Harper believes that the double nuclear fusion in the mildews, one in the oogonium and one in the ascus, necessitates a triple division in order to bring about the corresponding reduction in the number of the chromosomes. Harper also interprets the ascus as a spore mother cell.

Host Distribution. Some morphological species of the powdery mildews are limited to a single host. For example, *Podosphaera biuncinata* occurs only on *Hamamelis virginiana*, and *Uncinula geniculata* on *Morus rubra*. Others are confined to the species of a single genus of host plant, for example, *Uncinula circinata* on Acer, *Erysiphe aggregata* on Alnus. Again some occur on a number of different genera all of which belong to the same family, for example, *Erysiphe graminis* on various grasses. Several

of the mildews, however, have a very wide range of hosts. Perhaps the most striking cases are *Erysiphe polygoni* on 355 hosts belonging to 42 families, *E. cichoraceaum* on 280 hosts belonging to 27 families and *Phyllactinia corylea* on 144 hosts belonging to 36 families.

Several cases are known where two or more different species of mildews occur on the same host. These may have the same or a different geographical distribution. For example, *Microsphaera alni* and *Phyllactinia corylea* both occur on the common hazelnut, *Corylus americana; Erysiphe polygoni* and *Microsphaera alni* occur on *Lathyrus venosus;* and three different mildews, *Sphaerotheca mors-uvae, Microsphaera grossulariae* and *Phyllactinia corylea* have been reported on *Ribes Grossularia.*

Biologic Specialization. In recent years a great deal of experimental work has been done to determine whether a mildew growing on one host can produce infection on another plant which is known to be infected by the same morphological species. Neger (39) was the first to show that some of the morphological species of mildews are broken up into biologic forms, limited to definite host plants. Marchal (35-36), Reed (45-49), Salmon (52-57), Steiner (63), and Voglino (68), have very greatly extended our knowledge regarding the biological specialization of different mildews.

Thus far one or more species of five genera-Uncinula, Erysiphe, Microsphaera, Phyllactinia and Sphaerotheca—have been tested for host specialization, no results as yet having been recorded for Podosphaera. Most of the data obtained, however, are very incomplete except possibly in the case of three species of Erysiphe, namely *E. Polygoni, E. cichoraceaum* and *E. graminis,* and one species of *Sphaerotheca, Sph. humuli.*

The grass mildew, *Erysiphe graminis,* has proven to be exceptionally favorable for studies on biologic specialization. The result has been the discovery of a large number of facts bearing upon this problem. As already noted this morphological species occurs on approximately sixty different grasses. So far, however, the work indicates that in practically every case the biologic forms are restricted to the species of a single genus. For example, conidia from wheat will not infect barley, oats nor rye; conidia from barley

will not infect wheat, oats nor rye. In other words, in every case the mildew on one cereal is unable to pass over onto the species of other cereals.

Not all species of a particular genus, however, may be susceptible to the mildew. For example, the mildew on barley will infect the common barley and also *Hordeum decipiens, H. hexastichon, H. intermedium, H. bulbosum, H. distichum, H. maritinum* and *H. zeocriton,* but will not pass over onto *H. jubatum, H. murinum, H. secalinum nor H. sylvaticum.* Young plants of *Hordeum nodosum* are easily infected with the barley mildew but older plants are immune. A similar case has been found by Salmon (56) among the brome grasses. As a result of his work upon the mildews of the brome grasses, Salmon believes that there are four or perhaps five biologic forms within this one genus alone.

The wheat mildew, while able to pass over onto one or more varieties of every species of Triticum tested, is not capable of infecting all of the varieties of wheats. In a recent paper (49) I published the results of tests with seventy-eight varieties distributed among nine different species of this genus. Of these seventy-eight varieties four proved to be immune, two belonging to *T. dicoccum* and two to *T. vulgare.* In a few other cases the percentage of infection was rather low but in a great majority of cases the percentage of infection approached 100.

In some unpublished results I have been able to transfer the wheat mildew to different species of Aegilops. Several species were tested and nearly all of them proved highly susceptible. If Aegilops is to be regarded as a distinct genus as some systematists believe, we have a case of one biological form of grass mildew occurring on the species of two different genera. A similar relation is found in the case of the oat mildew, for I have been able to confirm Marchal's statement that the conidia from oats are able to infect seedlings of *Arrhenatherum elatius,* although the percentage of infection is not very high.

Well developed biologic forms have been found on other grasses. The mildew on species of Agropyron are confined to the hosts of this genus. Similarly the orchard grass mildew is confined to *Dactylis glomerata* and the blue grass mildew to species of Poa.

In addition to the grass mildew very full results have been obtained with *Erysiphe cichoraceārum*. As already noted, this mildew occurs upon 280 hosts belonging to 27 families. It is therefore a very cosmopolitan species. The results indicate, however, that it is broken up into biologic forms. I (47) have found that distinct forms occur on cucurbits, asters and golden rods. I have also found that the cucurbit mildew occurs on at least eleven species of cucurbits belonging to seven genera. Six other species were also slightly infected. In fact only three species of cucurbits tested remained entirely resistant to the mildew. I further found that plants of *Plantago rugelii* and of *Helianthus annuus* could be infected by the mildew growing upon the cucurbits. In this case therefore this biologic form not only occurs on several genera of a single family but even passes out beyond the limits of the family.

Salmon (56) in his work on the mildew of the brome grasses, and Steiner (63) more recently in his work with the mildew of Alchemilla, have described what they call "bridging species." Salmon found that the mildew on *Bromus racemosus* failed to infect *B. commutatus* (twelve trials), while it infected *B. hordeaceus* in one hundred per cent of the cases (thirty-four trials). Furthermore, conidia from *B. commutatus* failed to infect *B. racemosus* (thirty-six trials), while the mildew occurring in nature on *B. hordeaceus* infected *B. commutatus* (forty out of forty-nine trials). From these data, Salmon concludes that *B. hordeaceus* may act as a "bridge" for the mildews on *B. racemosus* and *B. commutatus*. Salmon tested this in one case by infecting *B. hordeaceus* with conidia from *B. racemosus*. The conidia produced on the former were then used to infect *B. commutatus*. Similarly Steiner regards *Alchemilla pastoralis* as a "bridge" for *Sphærotheca humuli* to pass from *A. connivens* to *A. micans*.

The question of the degree of biologic specialization in other mildews is one of great interest and one which can be attacked with relative ease. There are many cases of peculiar host distribution which should be investigated from the physiological standpoint. For example, *Microsphaera diffusa* is reported by Salmon in his monograph as occurring on twelve herbaceous legumes and three species of *Symphoricarpos*, a shrubby plant belonging to the Caprifoliaceæ.

To be sure a distinct species, based on morphological characters, is recognized by some as occurring on Symphoricarpos. Infection experiments would determine whether the mildew on the legumes is transferable to Symphoricarpos or not and might indicate whether the minor morphological differences are of sufficient importance to regard the form on Symphoricarpos as a distinct species.

It is further of interest that *Phyllactinia corylea* occurs on such a wide range of hosts and that the one species of the genus has a world wide distribution. While certain workers have described other species of the genus yet the great morphological similarity of this mildew on its various hosts is very striking. Voglino (68) has found some evidence for biologic specilization in this mildew.

Economic Importance. The mildews are obligate parasites and as such frequently cause a great deal of injury to their hosts. While as a general rule these fungi are not considered as destructive as the rusts and smuts, still there are many plants of economic importance that are seriously attacked by some species of powdery mildew.

The powdery mildew of the grape, *Uncinula necator,* has for a long time been recognized as a serious menace to the culture of grapes in various parts of Europe. In 1847 Berkeley (7) reported that "the grapes in the neighborhood of Margate (England) have for the past two years been attacked by a peculiar mildew of a most destructive character." Very soon after this the disease was reported from the vineyards of southern France and other European countries, causing destruction to the grape harvest.

The American gooseberry mildew, *Sphaerotheca mors-uvae,* has proven very destructive to the English varieties of gooseberries, so that their cultivation in this country is attended with great loss. The fungus attacks especially the fruit, covering the berries with a close felt-like mycelium. The mycelium becomes dark colored and thick-walled with age and the perithecia are imbedded in it. In recent years (21, 58) the mildew has occurred in epidemic form in England and other European countries. Its appearance everywhere has occasioned great loss to growers of gooseberries, not only by destroying the year's crop of fruit but also by weakening the bushes themselves through injury to twigs and leaves. It is interesting to

note that the European gooseberry mildew, *Microsphaera grossulariæ,* is not ordinarily troublesome although injury has been reported, the affected leaves becoming shrivelled and falling prematurely.

The rose mildew, *Sphaerotheca pannosa,* is often very destructive to roses. While especially likely to attack roses cultivated in the greenhouse, the fungus also attacks certain varieties in the garden. The crimson rambler is notably susceptible, for the fungus develops on the young leaves causing these to curl and arch; the young stems are also attacked and more or less deformed. It also attacks the flower buds forming a white mealy growth and blasting the flowers. The conidia are formed in great abundance and the disease spreads very rapidly.

The hop, in many regions, suffers serious injury from the spread of the hop mildew, *Sphaerotheca humuli.* The worst damage is done when the disease attacks the cones causing them to shrivel up. In some parts of England this disease is much dreaded by the hop growers. Comparatively recently the hop mildew has become serious in the hop yards of New York (9). In some counties the entire hop crop has been ruined by the ravages of this fungus while in others the yield has been decreased and the quality of the crop much impaired.

Among other plants that are sometimes seriously attacked by the mildews the following may be mentioned: Grasses are sometimes seriously injured by the spread of *Erysiphe graminis.* Anderson (2) reports that this mildew in the northwestern states "affects chiefly the Poas and is especially damaging to *P. tenuiflora,* one of our most valued forage grasses." Stewart (64) has reported the occurrence of the mildew on wheat in the spring but, although the disease spreads very rapidly, no serious permanent injury to the wheat crop results. Cucumbers when forced in the greenhouse are sometimes severely attacked by *Erysiphe cichoraccarum.* Nursery stock, as apples, peaches and cherries, are frequently damaged by powdery mildews.

As a general rule it is not difficult to control the outbreaks of diseases due to powdery mildews. Repeated experience has shown that flowers of sulphur, dusted on the infected plants, is a satisfac-

tory remedy. Most of the mildews seem to be controlled by this treatment, especially when prompt measures are taken at the first indication of an outbreak. A relatively strong solution of potassium sulphide—one ounce in two gallons of water—is also effective in the treatment of some diseases caused by mildew.

Pathological Effects. As a general thing the mildews do not cause any striking pathological changes in the cells of the host. Ordinarily no appreciable malformation occurs or hypertrophy. However, an enlargement of the twigs of Physocarpus, similar to Witches' Brooms, are produced by the development of *Sphaerotheca humuli.*

One effect of some of these mildews is very striking. When Maple leaves infected with *Uncinula circinata* are collected in the late fall they will be found to show characteristic yellow and green areas. Examination shows that the green areas are infected with the mildew. The infected host cells are stimulated to retain their green color longer than the other cells of the leaf. A similar effect may be seen on grass leaves when badly covered with the mildew. The results may be made more striking by placing leaves of barley, for example, in a moist glass chamber and inoculating with conidia from barley. In three to four days numerous infected areas will be distinctly visible and possess a deep green color while the other portions of the leaves will be a pale yellow.

Collection, Preservation and Cultivation of the Powdery Mildews. The powdery mildews are usually conspicuous objects on leaves and other parts of living plants. Sometimes careful search is needed to locate the perithecia. When hunting for mildews one needs to examine both surfaces of the leaves for many forms occur mainly or entirely on the under surface of leaves. This is particularly true of *Phyllactinia corylea.*

Special care, of course, must be taken to properly identify the host plant. In fact it is generally a good plan to collect flowering or fruiting parts of the host and keep these with the infected leaves.

For the systematic study of the powdery mildews dry material is very satisfactory. Infected parts of plants are collected and

placed between driers for a few days. The material is then transferred to suitable envelopes, properly labeled, and laid aside for future study.

Many of the mildews are easily cultivated in greenhouses and afford exceptionally fine material for the study of various problems. In general a succession of crops of young hosts must be provided so that the mildew will be able to spread over on to the young plants. The grass mildew on various hosts, when once secured, may easily be propagated by planting additional seed of the proper hosts at intervals of one to four weeks. Various other mildews are also readily propagated in a similar manner. The writer has successfully cultured for long periods the mildews on cucurbits, goldenrod, aster, Erigeron, apple, sunflower, various cereals and grasses, etc. As pointed out by Melhus (37) the sunflower mildew is particularly favorable for class use because of the readiness with which perithecia appear upon the host.

The writer has experienced a great deal of difficulty in propagating the mildews during the summer months. The high temperature of the greenhouse seems to be the controlling factor. The mildew, however, is especially infested by thrips, a small insect which seems to spread very rapidly during the summer season.

Classification. The powdery mildews have long been an object of study from the systematic standpoint. Practically all of the earlier mycological workers have devoted more or less attention to the group. Probably the first mention made of one of these fungi was by Linnaeus in *Species Plantarum* (1753) under the name of *Mucor Erysiphe*. Following Linnaeus, Persoon (42, 43), Rebentisch (44), (who published the first illustration), de Candolle (13), Fries (24), and others made additions to our knowledge of mildews. The most important papers dealing with the systematic arrangement of these fungi are those by Wallroth (69, 70) (1819) who insisted upon the distinction of species on the basis of morphological characters and not by the host plant upon which they grew; by Schweinitz (60) (1834), who described several North American forms; by Léveillé (33) (1851), who divided the group into six genera, based upon the number of asci in the perithecium and the characters of the appendages, the names and limits of these genera

being retained to the present day; by the Tulasne brothers (66) (1861), who described and very fully illustrated by exceptionally fine copper plates sixteen species, although they placed them all under one genus—Erysiphe; by Cooke & Peck (14) (1872) who listed the mildews of the United States; by Burrill (12) (1892) who described the North American forms then known; by Salmon (50) (1900) who has monographed the group with exceptional completeness and whose work is the standard at the present time.

Many lists from various states have also been published. These give us much desired information regarding the occurrence and distribution of the mildews in the United States. Among the more important of these state lists the following may be mentioned: Anderson (Iowa) (1), Anderson (Montana) (2, 3), Atkinson (Carolina and Alabama) (4), Brannon (Indiana) (10), Burrill and Earle (Illinois) (11), Davis (Wisconsin) (17, 18, 19, 20), Farlow (Massachusetts) (22), Freeman (Minnesota) (23), Griffiths (northwestern states) (26), Harkness and Moore (California) (27), Lawrence (Washington) (32), Millspaugh and Nuttall (West Virginia) (38), Selby (Ohio) (61), Tracy and Earle (Mississippi) (65), Underwood and Earle (Alabama) (67), Walters (Kansas) (71).

In the following classification of the *Erysiphaceæ* Salmon (50, 51) is largely followed. Most of the facts stated are taken from his monograph and supplementary notes.

Salmon in his monograph (50) recognizes six genera, forty-nine species and eleven varieties.

Saccardo on the contrary recognizes a much larger number of species. Of Salmon's species and varieties, thirty-one species and seven varieties are found in North America. Of these thirteen species and five varieties have been reported only from this continent.

Some interesting cases of distribution may be noted. The maple mildew of North America is *Uncinula circinata,* while a different species, *A. aceris* is reported on the maples of Europe. *Sphaerotheca morse-uvae* in North America specially attacks species of Ribes; in Europe this same form is reported on species of Euphorbia. Very recently, as already noted, this mildew has also appeared on Ribes

in Europe, but it is thought to have been introduced from America. *Microsphaera alni* is very common on the lilac, *Syringa vulgaris,* in this country, but according to Magnus (34) is not found on this host in Europe, although the fungus on other hosts is quite common.

Following Léveillé, Salmon divides the Erysiphaceæ into six genera[1] and uses the same generic names as proposed by Léveillé. The following keys, which are based on Salmon's monograph and which are quite generally used in this or in slightly different form, may serve to differentiate the genera and species.

Key to Genera

A. Perithecium containing a single ascus B.
  B. Appendages unbranched, more or less flexuous, arising from the base of the perithecium.....*Sphærotheca.*
  B. Appendages one to several times dichotomously branched at the apex .....*Podosphæra.*
A. Perithecium containing several asci C.
  C. Appendages without bulbous enlargement at the base D.
    D. Appendages generally straight, dichotomously branched at the apex .....*Microsphæra.*
    D. Appendages simple, uncinate or spirally inrolled at the apex. .....*Uncinula.*
    D. Appendages simple or irregularly branched, more or less flexuous, usually somewhat similar to the mycelial hyphæ, not dichotomously branched nor uncinate at the apex....*Erysiphe.*
  C. Appendages simple, straight, rigid, with a bulbous enlargement at the base .....*Phyllactinia.*

Sphaerotheca Léveillé. (Plate XVI, Figs. 38, 38a)

The perithecia are subglobose, containing a single ascus which is regularly 8-spored. The appendages are flexuous, brown or colorless, spreading horizontally and often interwoven with the mycelium which they frequently resemble; they are simple or rarely branched, sometimes lacking.

Sphærotheca is represented by five species and one variety, all of which have been reported from the United States.

1. Salmon (59) has since placed *Erysiphe taurica* in a new genus by itself—Oidiopsis—making in all seven genera.

KEY TO SPECIES

A. Mycelium persistent, thick, pannose, forming dense patches composed of special hyphæ, in which the perithecia are more or less immersed B.
B. Persistent mycelium usually satiny and shining, white, sometimes becoming gray or pale brown.....*S. pannosa* (Wallr.) Lév.
B. Persistent mycelium dark brown C.
C. Inner wall of the perithecium separating from the outer; hyphæ of persistent mycelium very tortuous.....*S. lanestris* Harkn.
C. Inner wall not separating, hyphae straighter.....
.....*S. mors-uvae* (Schw.) B. & C.
A Mycelium without these characters D.
D. Perithecia 60-78μ in diameter, ascus 60-75x42-50μ; inner wall of perithecium separating from the outer..*S. phytoptophila* K. & S.
D. Perithecia 50-120μ in diameter, ascus 45-90x50-72μ; inner wall scarcely separating from the outer E.
E. Cells of outer wall of perithecium 10-20μ wide, averaging 15μ
.....*S. humuli* (DC.) Burrill.
E. Cells of outer wall of perithecium 20-30 (rarely 40)μ wide, averaging 25μ.....*S. humuli* var. *fuliginea* (Schlecht.) Salm.

Hosts:

Sphærotheca pannosa; Rosa (various species).
S. lanestris: *Quercus agrifolia, Q. alba, Q. macrocarpa.*
S. mors-uvæ: *Ribes* (various species).
S. phytoptophila: *Celtis occidentalis.*
S. humuli: Agrimonia striata, Geranium maculatum, Geum canadense, Physocarpus opulifolius.
S. humuli var. *fuliginea*: *Bidens chrysanthemoides, B. frondosa, Erigeron annuus, Taraxacum officinale.*

PODOSPHÆRA KUNZE. (Plate XVI, Figs. 34, 34a).

Perithecia globose, or globose-depressed, containing a single ascus which is 8-spored. The appendages are equatorial or apical, dark brown or colorless, dichotomously branched at the apex, ultimate branches simple and straight or swollen and knob-shaped.

The genus contains four species and one variety, all, except one species, being represented in the United States.

Key to Species

A. Basal appendages present in addition to the apical, the latter usually unbranched.....*P. leucotricha* (Ell. & Everh.) Salm.
A. No basal appendages present B.

B. Appendages arising from near the apex of the perithecium, somewhat erect and fasciculate, one to eight times the diameter of the perithecium, dark brown for more than half their length .....*P. oxyacanthæ* var. *tridactyla* (Wallr.) Salm.

B. Appendages equatorially inserted and more or less spreading C.

C. Appendages colorless, or faintly tinged with brown at the base, branched apex not swollen.....*P. biuncinata* C. & P.

C. Appendages dark brown for more than half their length, ultimate branches of the apex knob-shaped.....

.....P. *oxyacanthæ* (DC.) De Bary.

Hosts:

P. leucotricha: *Pyrus malus.*
P. biuncinata: *Hamamelis virginiana.*
P. oxyacanthæ: *Prunus* (various species).
P. oxyacanthæ var. *tridactyla*[1]: *Spiræa Douglasii.*

Uncinula Léveillé. (Plate XVI, Figs. 37, 37a).

This genus is easily distinguished by the uncinate apex of the appendages. The perithecia are globose or globose-depressed and contain several asci, two to eight spored. The appendages are simple in all American forms.

There are eighteen species and two varieties. Of these ten species occur in the United States.

Key to Species

A. Appendages colored for half their length or more.....
.....*U. necator* (Schw.) Burrill.

A. Appendages colorless B.

B. Asci containing 2-3 spores C.

C. Perithecia very large 215-320μ in diameter; more than 30 asci in the perithecium.....*U. polychaeta* (B. & C.) Ellis

C. Perithecia averaging 130μ; asci 8-20 in the perithecium....
.....*U. macrospora* Peck.

B. Asci containing 4-8 spores D.

D. Appendages delicate, narrow, 3-4μ wide; asci 4-7 spored E.

E. Perithecia 150-200μ in diameter; asci about 25.....
.....*U. confusa* Massee.

E. Perithecia 86-122μ in diameter; asci 5-8 G.

G. Appendages 50-160, ½-¾ times the diameter of perithecium.....*U. parvula* C. & P.

1. Reported only from Washington.

G. Appendages 24-46, 1½-2 times the diameter of perithecium, often geniculate.....*U. geniculata* Gerard.

D. Appendages stouter, wider, or if narrow with asci 8-spored F.

F. Appendages abruptly flexuose, about equalling the diameter of perithecium, spores usually 8.....*U. flexuosa* Peck.

F. Appendages all straight H.

H. Appendages thick walled, refractive or rough at base, perithecia 64-146μ in diameter.....*U. clintonii* Peck.

H. Appendages thin walled throughout I.

I. Perithecia 90-175μ in diameter, averaging 135μ; asci containing 4-6 spores.....*U. salicis* (DC.) Winter.

I. Perithecia 160-225μ in diameter, averaging 190μ; asci containing 7-8 spores.....*U. circinata* C. & P.

Hosts:

Uncinula necator: *Psedera quinquefolia, Vitis* (various species).
U. polychaeta[1]: *Celtis occidentalis.*
U. macrospora: *Ulmus americana, U. fulva.*
U. confusa[2]: *Celtis occidentalis.*
U. parvula: *Celtis occidentalis.*
U. geniculata: *Morus rubra.*
U. flexuosa: *Aesculus glabra.*
U. clintonii: *Tilia americana.*
U. salicis: *Populus* (various species), *Salix* (various species).
U. circinata: *Acer saccharinum.*

Erysiphe Hedw. (Plate XVI. Figs. 36, 36a).

Perithecia are generally globose and contain several asci, 2-8 spored. Appendages are floccose, simple or irregularly branched, never with a definite apical branching, sometimes obsolete, usually more or less similar to the mycelium and interwoven with it.

The genus contains eight species and one variety of which seven species and the variety occur in the United States.

Key to Species

A. Perithecia large, 135-280μ in diameter, averaging 200μ B.

B. Perithecia immersed in a lanuginose persistent mycelium; asci not containing spores on the living host.....*E. graminis* DC

B. Perithecia not immersed in a lanuginose persistent mycelium; asci containing spores on the living host C.

1. Reported only from S. Carolina, Alabama and Mississippi.
2. Never found but once and then associated with *U. parvula.*

C. Asci containing eight spores, rarely six or seven; spores somewhat spherical, 16-20x10-15μ.....*E. aggregata* (Peck) Farlow.

C. Asci containing four to six spores; spores 20-22x10-12μ..... .....*E. polygoni* var. *sepulta* (Ell. & Everh.) Salm.

C. Asci containing two spores; spores 28-40x18-22μ; perithecia at maturity becoming cup-shaped.....*E. taurica* Lév.

A. Perithecia smaller, 65-180μ, not immersed in a lanuginose mycelium D.

D. Asci not containing spores on the living host; haustoria lobed.... .....*E. galeopsidis* DC

D. Asci generally containing spores on the living host; haustoria not lobed E.

E. Perithecia containing 4-25 asci, usually 10-15; asci 58-90x30-50μ; spores generally two, 20-28x12-20μ.....*E. cichoracearum* DC.

E. Perithecia containing few asci, 2-8, rarely as many as 22; asci 46-72x30-45μ; spores 3-8, rarely 2, 19-25x9-14μ.*E. polygoni* DC.

A. Perithecia small, 52-60μ in diameter, containing usually three asci; asci 48-50x28-36μ; asci two, rarely three, spored.....*E. trina* Harkn.

Hosts:

Erysiphe graminis: *Agropyron repens, Avena sativa, Dactylis glomerata, Hordeum vulgare, Poa pratensis, Secale cereale, Triticum vulgare.*

E. aggregata: *Alnus incana* (catkins).

E. galeopsidis: *Scutellaria latifolia, Stachys tenuifolia.*

E. polygoni: *Astragalus canadensis, Clematis virginiana, Lathyrus venosus, Polygonum aviculare, Ranunculus abortivus.*

E. polygoni var. *sepulta*:[1] *Bigelovia graveolens.*

E. cichoracearum: *Actinomeris alternifolia, Ambrosia trifida, Aster cordifolius, A. laevis, A. sagittifolius, Eupatorium purpureum, Helianthus annuus, Cucumis sativus, Cucurbita maxima, Solidago canadensis.*

E. trina[2]: *Quercus agrifolia.*

E. taurica[3]: *Heliopsis scabra.*

MICROSPHÆRA Léveillé. (Plate XVI. Figs. 39, 39a).

The perithecia are globose to globose-depressed and contain several asci, 2-8 spored. The appendages are not interwoven with the mycelium; they are divided several times in a dichotomous manner at the apex.

1. Reported from Rocky Mountain States.
2. Reported only from California.
3. Reported by Salmon as an old world species but recorded by Anderson (1) from Iowa.

The genus is represented by thirteen species and six varieties of which five species and four varieties occur in North America.

Key to Species

A. Appendages 2½-7 times the diameter of the perithecia, usually much contorted and angularly bent; apical branching of appendages very irregular and lax, with the branches flexuous and more or less curled.....*M. euphorbiæ* (Peck) B. & C.

A. Appendages long or short without above characters B.

B. Tips of some or all of the ultimate branches of the appendages recurved C.

C. Appendages long and flaccid D.

D. Apex of appendages much branched, ornate, more or less close; spores 22-26x12-15μ.....*M. alni* var. *extensa* (C. & P.) Salm.

D. Apex of appendages less branched, more or less widely forked, or branching close and simple; spores 18-23x9-13μ.....*M. alni* var. *vaccinii* (Schw.) Salm.

C. Appendages short, not exceeding 2½ times the diameter of the perithecium E.

E. Appendages more or less contorted, apical branching very lax and irregular.....*M. alni* var. *ludens* Salm.

E. Appendages not contorted, apical branching closer and regular; tips regular, recurved F.

F. Axis of some appendages not dividing dichotomously at the apex, but bearing sets of opposite branches.....*M. alni* var *calocladophora* (Atk.) Salm.

F. Appendages regularly dichotomous at apex.....*M. alni* (Wallr.) Salm.

B. Tips of appendages not recurved G.

G. Appendages 3-7 times diameter of perithecia; colored, nearly to apex.....*M. Russellii* Clinton.

G. Appendages colorless H.

H. Branching of appendages lax, irregular; ultimate branches long, forming a narrow fork.....*M. diffusa* C. & P.

H. Branching closer and more regular; apex of appendages with very short primary and secondary branches, more or less digitate.....*M. grossulariæ* (Wallr.) Lev.

Hosts:

M. euphorbiae: *Euphorbia corallata.*

M. alni: *Gleditsia triacanthos, Lathyrus odoratus, Platanus occidentalis, Syringa vulgaris, Viburnum Lentago.*

M. alni var. *vaccinii*: *Vaccinium* (various species).

M. alni var. *ludens*[1]: *Vicia americana.*
M. alni var. *extensa*: *Quercus* (various species).
M. alni var. *calocladophora*[2]: *Quercus aquatica.*
M. Russellii: *Oxalis stricta.*
M. diffusa: *Desmodium canadense, Lespedeza capitata, Symphoricarpos orbiculatus.*
M. grossulariæ: *Ribes nigrum, Sambucus canadensis.*

PHYLLACTINIA Léveillé. (Plate XVI. Figs. 35, 35a).

This genus is easily recognized by the large (140-270μ in diam.) globose-depressed perithecia with the equatorial rigid, colorless, acicular appendages with a bulbous swelling at the base. The perithecia contain many asci which are regularly 2-spored, rarely 3-spored. The apex of the perithecium is provided with numerous crowded, branched penicillate cells which arise from the outer cells of the perithecial wall.

The mycelium of this genus is characteristically internal, developing in the intercellular spaces of the leaf. Special branches, haustoria, penetrate into the cells of the spongy parenchyma.

This genus is widely distributed and is represented by a single species—*Phyllactinia corylea* (Pers.) Karst.

Hosts:

Betula alba, Celastrus scandens, Cornus stolonifera, Corylus Americana, Ostrya virginiana.

Host Index. The following list includes about one hundred and seventy-five hosts of the Erysiphaceæ. The list is by no means intended as a complete one of the powdery mildews of the United States, but it does include the common hosts, most of which have a wide distribution and upon which the various species of mildews may be found. Collections of nearly all of these are found in the herbarium of the writer. A few are taken from the records of different state lists. In naming the hosts, Gray's New Manual of Botany, revised by Robinson and Fernald, is strictly followed.

1. Reported only from S. Dakota and Montana.
2. Reported only from S. Carolina, Alabama and Mississippi.

Host	Fungus
Acer rubrum L.	Uncinula circinata C. & P.
Acer saccharum Marsh.	Uncinula circinata C. & P.
Acer saccharinum L.	Uncinula circinata C. & P.
Actinomeris alternifolia (L.) DC.	Erysiphe cichoracearum DC.
Aesculus glabra Willd.	Uncinula flexuosa Peck.
Agrimonia striata Michx.	Sphærotheca humuli (DC.) Burr.
Agropyron repens (L.) Beauv.	Erysiphe graminis DC.
Alnus incana (L.) Moench.	Erysiphe aggregata (Peck) Farl.
Ambrosia artemisifolia L.	Erysiphe cichoracearum DC.
Ambrosia trifida L.	Erysiphe cichoracearum DC.
Amphicarpa monoica (L.) Ell.	Erysiphe polygoni DC.
Apios tuberosa Moench.	Microsphæra diffusa C. & P.
Aquilegia canadensis L.	Erysiphe polygoni DC.
Aquilegia coerulea James.	Erysiphe polygoni DC.
Aster cordifolius L.	Erysiphe cichoracearum DC.
Aster laevis L.	Erysiphe cichoracearum DC.
Aster paniculatus Lam.	Erysiphe cichoracearum DC.
Aster puniceus L.	Erysiphe cichoracearum DC.
Aster sagittifolius Wedemeyer.	Erysiphe cichoracearum DC.
Aster Tradescanti L.	Erysiphe cichoracearum DC.
Astragalus canadensis L.	Erysiphe polygoni DC.
Avena sativa L.	Erysiphe graminis DC.
Betula alba L. var. papyrifera (Marsh) Spach.	Phyllactinia corylea (Pers.) Karst.
Bidens cernua L.	Sphærotheca humuli (DC.) Burr. var. fuliginea (Schlecht.) Salm.
Bidens lævis (L.) BSP.	Sphærotheca humuli (DC.) Burr. var. fuliginea (Schlecht.) Salm.
Bidens frondosa L.	Sphærotheca humuli (DC.) Burr. var. fuliginea (Schlecht.) Salm.
Bigelovia graveolens A. Gray.	Erysiphe polygoni DC. var. sepulta (E. & E.) Salm.
Carpinus caroliniana Walt.	Microsphæra alni (Wallr.) Salm.
Castanea dentata (Marsh.) Borkh.	Microsphæra alni (Wallr.) Salm.
Catalpa speciosa Warder.	Microsphæra alni (Wallr.) Salm. var. vaccinii (Schw.) Salm.
Ceanothus americanus L.	Microsphæra alni (Wallr.) Salm.
Celastrus scandens L.	Phyllactinia corylea (Pers.) Karst.
Celtis occidentalis L.	Sphærotheca phytoptophila K. & S.
Celtis occidentalis L.	Uncinula polychæta (B. & C.) Ellis
Celtis occidentalis L.	Uncinula parvula C. & P.
Chelone glabra L.	Erysiphe galeopsidis DC.
Cirsium lanceolatum (L.) Hill.	Erysiphe cichoracearum DC.
Cirsium muticum Michx.	Erysiphe cichoracearum DC.

Clematis virginiana L.....Erysiphe polygoni DC.
Cornus alternifolia L. f.....Microsphæra alni (Wallr.) Salm.
Cornus stolonifera Michx.....Phyllactinia corylea (Pers.) Karst.
Corylus americana Walt.....Microsphæra alni (Wallr.) Salm.
Corylus americana Walt.....Phyllactinia corylea (Pers.) Karst.
Cratægus Crus-galli L.....Podosphæra oxyacanthæ (DC) de B.
Cratægus coccinea L.....Podosphæra oxyacanthæ (DC.) de B.
Crepis acuminata Nutt.....Erysiphe cichoracearum DC.
Cucumis sativus L.....Erysiphe cichoracearum DC.
Cucurbita maxima Duchesne.....Erysiphe cichoracearum DC.
Cucurbita Pepo L.....Erysiphe cichoracearum DC.
Dactylis glomerata L.....Erysiphe graminis DC.
Desmodium canescens (L.) DC.....Microsphæra diffusa C. & P.
Desmodium canadense (L.) DC.....Microsphæra diffusa C. & P.
Desmodium paniculatum (L.) DC.....Microsphæra diffusa C. & P.
Elymus striatus Willd.....Erysiphe graminis DC.
Erigeron annuus (L.) Pers.....Sphærotheca humuli (DC.) Burr. var. fuliginea (Schlecht.) Salm.
Erigeron canadensis L.....Sphærotheca humuli (DC.) Burr. var. fuliginea (Schlecht.) Salm.
Eupatorium urticæfolium Reichard...Erysiphe cichoracearum DC.
Eupatorium perfoliatum L.....Erysiphe cichoracearum DC.
Eupatorium purpureum L.....Erysiphe cichoracearum DC.
Euphorbia corollata L.....Microsphæra euphorbiæ (Peck) B. & C.
Euphorbia marginata Pursh.....Microsphæra euphorbiæ (Peck) B. & C.
Fraxinus americana L.....Phyllactinia corylea (Pers.) Karst.
Fraxinus Pennsylvanica Marsh.....Phyllactinia corylea (Pers.) Karst.
Galium Aparine L.....Erysiphe cichoracearum DC.
Geranium carolinianum L.....Sphærotheca humuli (DC.) Burr.
Geranium maculatum L.....Sphærotheca humuli (DC.) Burr.
Gerardia grandiflora Benth.....Sphærotheca humuli (DC.) Burr. var. fuliginea (Schlecht.) Salm.
Geum canadense Jacq.....Sphærotheca humuli (DC.) Burr.
Gilia micrantha (Kell.) A. Nels.....Sphærotheca humuli (DC.) Burr.
Gleditsia triacanthos L.....Microsphæra alni (Wallr.) Salm.
Grindelia squarrosa (Pursh.) Duval..Erysiphe cichoracearum DC.
Hamamelis virginiana L.....Podosphæra biuncinata C. & P.
Helenium autumnale L.....Erysiphe cichoracearum DC.
Helianthus annuus L.....Erysiphe cichoracearum DC.
Helianthus decapetalus L.....Erysiphe cichoracearum DC.
Helianthus strumosus L.....Erysiphe cichoracearum DC.
Helianthus tuberosus L.....Erysiphe cichoracearum DC.
Heliopsis scabra Duval.....Erysiphe taurica Lév.

Hordeum vulgare L.....Erysiphe graminis DC.
Humulus Lupulus L.....Sphærotheca humuli (DC.) Burr.
Hydrophyllum appendiculatum Michx.Erysiphe cichoracearum DC.
Hydrophyllum macrophyllum Nutt...Erysiphe cichoracearum DC.
Inula Helenium L.....Erysiphe cichoracearum DC.
Lathyrus ochroleucus Hook.....Microsphæra alni (Wallr.) Salm.
Lathyrus odoratus L.....Microsphæra alni (Wallr.) Salm.
Lathyrus palustris L.....Microsphæra alni (Wallr.) Salm.
Lathyrus venosus Muhl.....Erysiphe polygoni DC.
Lespedeza capitata Michx.....Microsphæra diffusa C. & P.
Ligustrum vulgare L.....Microsphæra alni (Wallr.) Salm.
Lonicera sempervirens L.....Microsphæra alni (Wallr.) Salm.
Lonicera tartarica L.....Microsphæra alni (Wallr.) Salm.
Lupinus perennis L.....Erysiphe polygoni DC.
Morus rubra L.....Uncinula geniculata Gerard.
Oenothera biennis L.....Erysiphe polygoni DC.
Ostrya virginiana (Mill.) K. Koch...Microsphæra alni (Wallr.) Salm.
Ostrya virginiana.....Phyllactinia corylea (Pers.) Karst.
Oxalis stricta L.....Microsphæra Russellii Clinton.
Parietaria Pennsylvanica Muhl.....Erysiphe cichoracearum DC.
Parnassia caroliniana Michx.....Erysiphe polygoni DC.
Phlox paniculata L.....Erysiphe cichoracearum DC.
Physocarpus opulifolius (L.) Maxim. Sphærotheca humuli (DC.) Burr.
Pisum sativum L.....Erysiphe polygoni DC.
Plantago major L.....Erysiphe cichoracearum DC.
Plantago Rugellii Dene.....Erysiphe cichoracearum DC.
Platanus occidentalis L.....Microsphæra alni (Wallr.) Salm.
Poa pratensis L.....Erysiphe graminis DC.
Polygonum aviculare L.....Erysiphe polygoni DC.
Polygonum erectum L.....Erysiphe polygoni DC.
Polygonum exsertum Small.....Erysiphe polygoni DC.
Polygonum scandens L.....Erysiphe polygoni DC.
Populus deltoides Marsh.....Uncinula salicis (DC.) Winter.
Populus grandidentata Michx.....Uncinula salicis (DC.) Winter.
Populus tremuloides Michx.....Uncinula salicis (DC.) Winter.
Prunus Besseyi Bailey.....Podosphæra oxyacanthæ (DC.) de B.
Prunus (cultivated cherry & plum)...Podosphæra oxyacanthæ (DC.) de B.
Psedera quinquefolia (L.) Greene....Uncinula necator (Schw.) Burr.
Pyrus malus L.....Podosphæra leucotricha (E. & C.) Salm.
Quercus alba L.....Microsphæra alni (Wallr.) Salm.
Quercus alba L.....Sphærotheca lanestris Harkn.
Quercus agrifolia Née.....Erysiphe trina Harkn.
Quercus agrifolia Née.....Sphærotheca lanestris Harkn.

Quercus aquatica Walt.....Microsphæra alni (Wallr.) Salm. var. calocladophora (Atk.) Salm.
Quercus macrocarpa Michx.....Sphærotheca lanestris Harkn.
Quercus macrocarpa Michx.....Microsphæra alni (Wallr.) Salm.
Quercus Muhlenbergii Engelm.....Microsphæra alni (Wallr.) Salm.
Quercus pedunculata Ehrh. var. fastigiata DC.....Microsphæra alni (Wallr.) Salm.
Quercus Prinus L.....Microsphæra alni (Wallr.) Salm. var. extensa (C. & P.) Salm.
Quercus rubra L.....Microsphæra alni (Wallr.) Salm. var. extensa (C. & P.) (Salm.)
Quercus velutina Lam.....Microsphæra alni (Wallr.) Salm. var. extensa (C. & P.) (Salm.)
Ranunculus abortivus L.....Erysiphe polygoni DC.
Ranunculus acris L.....Erysiphe polygoni DC.
Rhus glabra L.....Sphærotheca humuli (DC.) Burr.
Rhus typhina L.....Sphærotheca humuli (DC.) Burr.
Ribes Grossularia L.....Sphærotheca mors-uvae (Schw.) B. & C.
Ribes nigrum L.....Microsphæra grossulariæ (Wallr.) Lév.
Rosa (cultivated species, Crimson Rambler) .....Sphærotheca pannosa (Wallr.) Lév.
Rubus hispidus L.....Sphærotheca humuli (DC.) Burr.
Salix cordata Muhl.....Uncinula salicis (DC.) Winter.
Salix discolor Muhl.....Uncinula salicis (DC.) Winter.
Salix nigra Marsh.....Uncinula salicis (DC.) Winter.
Sambucus canadensis L.....Microsphæra grossulariæ (Wallr.) Lév.
Scutellaria lateriflora L.....Erysiphe galeopsidis DC.
Shepherdia argentea (L.) Nutt.....Sphærotheca humuli (DC.) Burr.
Sicyos angulatus L.....Erysiphe cichoracearum DC.
Solanum carolinense L.....Erysiphe cichoracearum DC.
Spiræa Douglasii Hook.....Podosphæra oxyacanthæ (DC.) de B. var. tridactyla (Wallr.) Salm.
Stachys palustris L.....Erysiphe galeopsidis DC.
Stachys tenuifolia Willd.....Erysiphe galeopsidis DC.
Symphoricarpos orbiculatus Moench...Microsphæra diffusa C. & P.
Syringa vulgaris L.....Microsphæra alni (Wallr.) Salm.
Taraxacum dumetorum Greene.....Sphærotheca humuli (DC.) Burr.
Taraxacum officinale Weber.....Sphærotheca humuli (DC.) Burr. var. fuliginea (Schlecht.) Salm.
Teucrium canadense L.....Erysiphe galeopsidis DC.
Tilia americana L.....Uncinula clintonii Peck.
Trifolium pratense L.....Erysiphe polygoni DC.
Triticum vulgare Vill.....Erysiphe graminis DC.

Troximon parviflorum Nutt.....Sphærotheca humuli (DC.) Burr. var. fuliginea (Schlecht.) Salm.
Ulmus fulva Michx.....Microsphæra alni (Wallr.) Salm.
Ulmus fulva Michx.....Uncinula macrospora Peck.
Vaccinium pennsylvanicum Lam.....Microsphæra alni (Wallr.) Salm. var. Vaccinii (Schw.) Salm.
Valeriana edulis Nutt.....Erysiphe cichoracearum DC.
Verbena hastata L.....Erysiphe cichoracearum DC.
Verbena stricta Vent.....Erysiphe cichoracearum DC.
Verbena urticæfolia L.....Erysiphe cichoracearum DC.
Vernonia Baldwini Torr.....Erysiphe cichoracearum DC.
Viburnum Lentago L.....Microsphæra alni (Wallr.) Salm.
Vicia americana Muhl.....Microsphæra alni (Wallr.) Salm. var. ludens Salm.
Vitis (cultivated grape).....Uncinula necator (Schw.) Burr.
Vitis cordifolia Michx.....Uncinula necator (Schw.) Burr.
Vitis vulpina L.....Uncinula necator (Schw.) Burr.
Zanthoxylum americanum Mill.....Phyllactinia corylea (Pers.) Karst.

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EXPLANATION OF FIGURES

Figures 1-3 are copied from Smith. Figures 6, 7, 9-33 are copied from Harper. The others are from drawings made by G. T. Kline.

Plate XIII.

Fig. 1. Haustorium of *Erysiphe polygoni* DC. on *Geranium maculatum.*

Fig. 2. Haustoria of *Uncinula salicis* (DC.) Winter on *Salix discolor.* One haustorium is located in the epidermal cell, while the other is in a subepidermal cell.

Fig. 3. Haustorium of *Erysiphe graminis* DC. on Poa.

Fig. 4. Three conidiophores of *Erysiphe graminis* DC. The characteristic enlargement at the base of the conidiophores is well shown. (Magn. 228 times).

Fig. 5. Three germinating conidia of *Erysiphe graminis* DC. (Magn. 228 times).

Fig. 6. Section through a young perithecium of *Phyllactinia corylea* (Pers.) Karst. The ascogonium of five cells is shown; the penultimate cell is budding out in ascogenous hyphæ.

Fig. 7. Median section of an older perithecium of *Phyllactinia corylea*. A portion of the ascogonium and sections of the multinucleated ascogenous hyphæ are shown.

Fig. 8. Median section of a perithecium of *Uncinula salicis*. The section shows three asci, each with the primary ascus nucleus; surrounding the asci is the inner wall composed of cells filled with dense protoplasm; outside of these the outer wall whose cells are largely devoid of protoplasmic contents and have thick walls. Four young appendages are shown.

Plate XIV.

Figs. 9-20 *Sphærotheca castagnei* Lév.

Fig. 9. Oogonium and antheridial branch each containing one nucleus.

Fig. 10. Antheridial branch cut off and nucleus divided into two.

Figs. 11-12 Antheridium cut off from the stalk cell.

Fig. 13. Cell wall between antheridium and oogonium dissolved and the antheridial nucleus lying adjacent to the oogonial nucleus in the oogonium.

Fig. 14. Fusion of oogonial and antheridial nuclei; wall re-formed between antheridium and oogonium.

Fig. 15. Oogonium with fusion nucleus and surrounded by the first layer of wall cells.

Fig. 16. Oogonium surrounded by two layers of wall cells.

Fig. 17. Development of oogonium to form ascogonium. The latter now consists of two uninucleated cells.

Fig. 18. Young ascogonium with three nuclei, cell division not having occurred.

Fig. 19. Completely developed ascogonium with the cells of the inner layer of the perithecial wall shown. The penultimate cell of the ascogonium is binucleated and is the young ascus.

Fig. 20. Young ascus with the primary ascus nucleus and two ascogonium cells.

Figs. 21-24. *Phyllactinia corylea* (Pers.) Karst.

Fig. 21. Ascus with two nuclei; chromatin strands distinctly oriented with reference to the central body.

Figs. 22-24. Stages in the fusion of the two nuclei to form the primary ascus nucleus.

PLATE XV.

Figs. 25-30. *Phyllactinia corylea* (Pers.) Karst.

Fig. 25. Ascus with primary ascus nucleus.

Fig. 26. Division of primary ascus nucleus; early stage in synapsis.

Fig. 27. Division of primary ascus nucleus; loosening of chromatin following synapsis.

Fig. 28. Division of primary ascus nucleus; equatorial plate stage showing eight chromosomes, and the central bodies with the well developed asters.

Fig. 29. Binucleated ascus following completion of the first division.

Fig. 30. Second division; late anaphase stages with eight chromosomes on each half of each spindle.

Figs. 31-32 *Erysiphe cichoracearum* DC.

Fig. 31. Spore formation; plasma membrane being formed by bending back of astral rays and their fusion to form an umbrella-shaped membrane.

Fig. 32. Plasma membrane of spore about complete.

Fig. 33. *Phyllactinia corylea* (Pers.) Karst. Ascus with two spores.

PLATE XVI.

Fig. 34. Perithecium of *Podosphæra oxyacanthæ* (DC.) De Bary, on cultivated cherry. (Magn. 50 times).

Fig. 34a. Ascus of *P. oxyacanthæ*. (Magn. 275 times).

Fig. 35. Perithecium of *Phyllactinia corylea* (Pers.) Karst. on *Betula alba*. (Magn. 50 times).

Fig. 35a. Ascus of *P. corylea* (magn. 275 times).

Fig. 36. Perithtecium of *Erysiphe polygoni* DC. on *Polygonum aviculare*. (Magn. 50 times).

Fig. 36a. Ascus of *E. polygoni*. (Magn. 275 times).

Fig. 37. Perithecium of *Uncinula salicis* (DC.) Winter on *Salix discolor*. (Magn. 50 times).

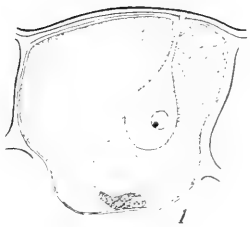
Fig. 37a. Ascus of *U. salicis*. (Magn. 275 times).

Fig. 38. Perithecium of *Sphærotheca Humuli* (DC.) Burr., var. *fuliginea* (Schlecht.) Salm. on *Taraxacum officinale*. (Magn. 50 times).

Fig. 38a. Ascus of *S. Humuli* var. *fuliginea*. (Magn. 275 times).

Fig. 39. Perithecium of *Microsphæra alni* (Wallr.) Salm. on *Syringa vulgaris*. (Magn. 50 times).

Fig. 39a. Ascus of *M. alni*. (Magn. 275 times).



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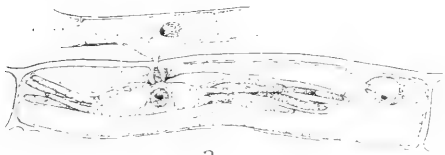

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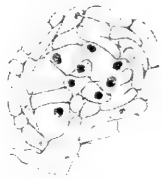

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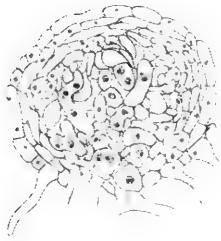

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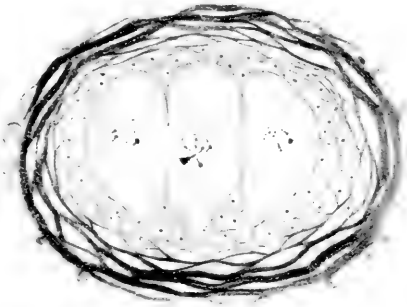

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PLATE XIII

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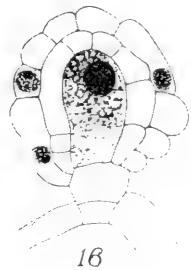

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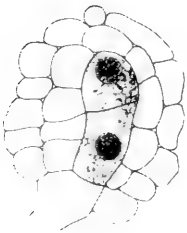

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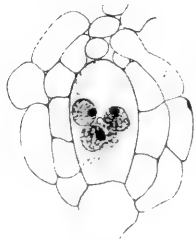

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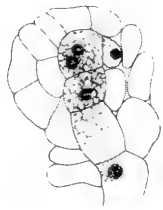

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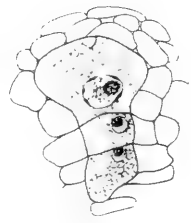

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PLATE XIV

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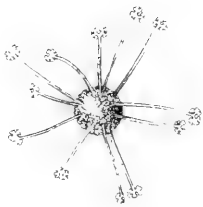
PLATE XV



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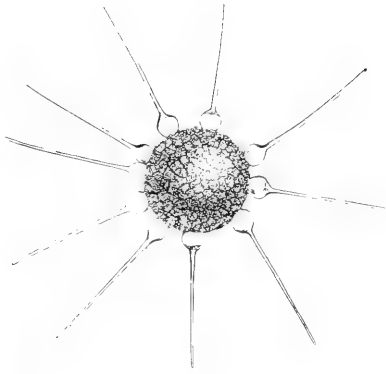

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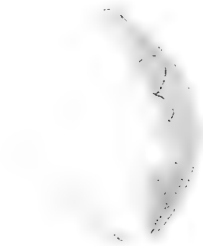

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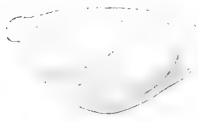

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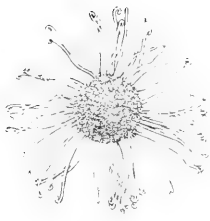

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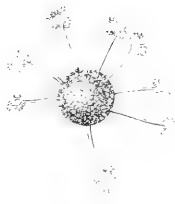

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PLATE XVI

A DESCRIPTIVE LIST OF THE CEPHALINE GREGARINES OF THE NEW WORLD

By Max M. Ellis.

Introduction.

Aside from Central Europe little is known of the Cephaline gregarine fauna of the world. Like many other groups of animals which have no large economic importance at present, cephaline gregarines have been neglected. Particularly is this true of the New World fauna. Gregarines are however deserving of more attention if only as objects of scientific interest, since they are easily obtainable and offer excellent material for both class work and experimental research. It is the object of the present paper to bring together the references to the new world species and some information regarding the group *Cephalina* Delage. Short descriptions and measurements have been added to aid in the determination of specimens.

History.

Although gregarines had been seen and reported by several writers before 1828, the first formal description of a genus and species of cephaline gregarines was made in that year by Leon Dufour (1828). He established the genus *Gregarina* and defined *G. ovata* from *Forficula auricularia* L., an earwig. He had however discussed gregarines in an earlier paper (1826). Dufour considered gregarines as peculiar worms and this idea dominated the work of several subsequent authors. Gregarines were variously regarded as parasitic worms, both Nematode and Trematode, and were even assigned to the plant kingdom by some. Koelliker (1848), was one of the first zoologists to maintain that gregarines are one-celled animals. The taxonomic knowledge of cephaline gregarines has been advanced particularly through the works of A. Schneider (1875 et. seq.), and of L. Leger (1892 et. seq.).

The first paper dealing with new world gregarines was published by Joseph Leidy in 1849. This included a short diagnosis of the genus *Gregarina* and the description of a new species, *G.*

larvata from *Julus marginatus*. In his discussion Leidy states that "in the state in which *Gregarina* is found, it would probably hold rank between the *Trematoda* and *Trichina*, the lowest of the Nematoidea". Subsequently Leidy published several other notes and descriptions of gregarines. No further attention was given the new world forms until Frenzel (1892), gave the descriptions and the results of some experimental work upon five new species of gregarines from Argentine Republic. Crawley (1903a,b; 1907), in a series of three articles offered the first connected account of the cephaline gregarines of the United States, describing new species from Leidy's unpublished manuscript and several from his own investigations.

At the present time 56 species, some of which are incompletely described, are known from North and South America. This undoubtedly is but an introduction to our fauna.

Anatomy and Life Cycle.

Cephaline gregarines are protozoan parasites, usually found in the alimentary canal of arthropods. They are most commonly taken in the free adult stage, the sporont, from the posterior portion of the alimentary canal of the host. A sporont (fig. 13), typically consists of two parts separated by a septum, so that it superficially appears to be made up of two cells. The anterior of these units is the protomerite, and the posterior, containing the nucleus, the deutomerite. The septum between the protomerite and the deutomerite is usually well developed but in some genera, as *Gamocystis* A. Schneider, the septum is wanting, the protomerite being represented by but a constriction. The other extreme is found in the peculiar gregarine *Taeniocystis mira* Leger from *Ceratopogon solstitialis* Winn., in which the deutomerite is divided by several granular septa. The outside coat of a sporont, the epicyte, is quite thin and rather firm as contrasted with the semi-fluid material, the endocyte, which fills it. Often just below the epicyte a thin clear zone, the sarcocyte, may be seen. The endocyte is usually quite dense and homogeneous although it may be almost clear, and may contain large and small granules and oil drops. The nucleus is suspended in this endocyte unattached as may be demonstrated by crushing a sporont, with pressure from a cover glass,

without crushing the nucleus, when the nucleus will be forced out of the epicyte. Often the nucleus is not visible but it may always be made so by staining with a weak solution of Iodine in Potassium Iodid (the usual Grams solution diluted one-half with water answers very well for this).

Since the life cycle of all cephaline gregarines is much the same, although those of the various species differ in detail, *Gregarina blattarum* Siebold from cockroach will be used as an example. The fusion of two sporonts in the alimentary canal of the first host produces a cyst. This is a prolate spheroid covered with a gelatinous envelope. After being discharged from the alimentary canal of the first host the cyst, if it be kept moist, passes through a series of internal changes, which result in the formation of sporocysts, commonly called spores. These are discharged from the cyst through long tubes, the sporoducts. The period during which the cyst produces sporocysts, up to the time when they are discharged, is known as the maturation period. The maturation changes, although begun before the cyst has left the body of the first host, rarely if ever are completed in the first host.* Each sporocyst, after it has been subjected to the proper conditions of moisture, discharges several sporozoites. Infection of the second host may take place either as the result of the ingestion of sporozoites, or of the sporocysts from which the sporozoites may be discharged. In either event the intracellular phase of the life cycle is begun by the sporozoite. This enters a cell of the alimentary canal of the new host and after a time develops into a minute gregarine, composed of three parts, a deutomerite, a protomerite and an epimerite, the latter being in front of the protomerite and joined to it. Later the young gregarine withdraws from the cell of the host so that only a portion of the epimerite remains within the cell, the remainder of the body being in the alimentary canal of the host. When the gregarine has attained a certain growth it leaves the cell entirely and becomes a free parasite in the canal, although still bearing the epimerite. This stage is the

*Crawley, (1903b, p. 641) has suggested, from the advanced stage of maturation in which he found the cysts of *G. achetaeabbreviatae* in the host, that sporocysts my occasionally be discharged in the host. Leger et Duboscq (1902, p. 412), report the sporocysts of *Pyxnia mobuszi* as occuring in the excrement of the host.

cephalont. The loss of the epimerite constitutes the change to the sporont stage and the cycle is completed.* The various stages differ somewhat with the several families and will be discussed in the diagnoses of the families.

Technique.

Gregarines are best studied while living. The alimentary canal may be withdrawn from a recently decapitated arthropod and teased in normal salt solution. Many species of gregarines will live for hours in either normal salt solution or Ringer's solution. When placed in water the osmotic tension usually causes them to swell up and burst. This difficulty may be overcome by the addition of a little white of egg. Permanent mounts are usually made with considerable difficulty if attempt be made to handle the individual animals. Balsam mounts may be made however by killing and staining portions of the alimentary canal of the host and teasing them when in balsam. Sections of the alimentary canal are also good, showing the intracellular stages as well as the free forms. The cysts are to be collected from the faeces of the host. By isolating several individuals of the host species in clean test tubes plugged with cotton, the faeces may be collected free from debris. The faeces should be examined with a low power glass after soaking in water. The cysts when removed from the faeces should be placed in a damp-cell on a slide. Care must be used to protect the cysts from mold.

Taxonomy.*

Since the sporonts of many species are quite similar the taxonomic characters are drawn for the most part from the epimerite, the cyst and the sporocyst. Often all of the stages were not at hand, so that many species are incompletely described, in the original diagnoses. In the descriptions given here the letters "P" and "D" refer to protomerite and deutomerite respectively, and the measurements are for average sporonts or spores.

*For a detailed account of the intracellular stages and their development see Leger and Duboscq, 1904.

*In making up the brief descriptions of the species given, data from specimens seen by the writer were used as far as possible; these wanting, the descriptions were composed from the figures given with the original diagnoses, which in the case of gregarines must correspond in general to the types of larger animals. The figures given here are from drawings by the writer unless otherwise credited.

CEPHALINA DELAGE

Sporozoans reproducing by sporulation only, which usually follows the permanent fusion of two adult individuals; gametes similar or dissimilar; young stages always intracellular; epimerite present in the first extracellular stage or at least represented in the last intracellular stages; adult generally divided by a septum into a deutomerite and a protomerite. This group includes the Polycystid Gregarines of authors.

Key to the Families of Cephalina

A. With a free cephalont stage.
  B. Sporonts forming associations;* epimerite simple.
    C. Septum of the satellite disappearing; dehiscence by simple rupture ..... *Didymophidæ*
    CC. Septum of the satellite present.
      D. Dehiscence of cyst by simple rupture..... *Hyalosporidæ*
      DD. Dehiscence of cyst by sporoducts..... *Gregarinidæ*
  BB. Sporonts not forming associations; epimerite usually not simple.
    E. Septum present in the sporont.
      F. Dehiscence of cyst by simple rupture.
        G. Sporocysts without spines..... *Actinocephalidæ*
        GG. Sporocyst with spines..... *Acanthosporidæ*
      FF. Dehiscence of cyst by a pseudocyst, either central or lateral.
        H. Epimerite symmetrical and symmetrically attached to the protomerite ..... *Stylocephalidæ*
        HH. Epimerite asymetrical or asymmetrically attached to the protomerite ..... *Dactylophoridæ*
    EE. Septum wanting in the sporont..... *Doliocystidæ*
AA. Epimerite represented only in the last intracellular stages. *Stenophoridæ*

*Two or more sporonts joined in tandem, see fig. 5; the first of these sporonts is termed the primite and the posterior individuals the satellites.

Didymophidæ

A family of one genus, the species of which are known only from Europe.

Didymophes F. Stein, *1848*, s. 186.

Type—*D. gigantea* F. Stein, *1848*, s. 186, t. 9, f. 40; from *Oryctes nasicornis* (L.) larvae,—*Coleoptera.*

Hyalosporidæ

This family is in part the *Gregarinidae* of authors. As here defined it includes only those Gregarinids whose cysts dehisce by simple rupture. Seven genera, one provisionally, are referred to

this family. One new world species is known, although doubtless several occur.

a. Septum present, protomerite and deutomerite distinct.
b. Sporocysts ellipsoidal to spindle-shaped; ends somewhat pointed.
c. Sporocyst with distinct equatorial swelling.....*Frenzelina*
cc. Sporocyst without equatorial swelling.....*Hyalospora*
bb. Sporocysts not ellipsoidal; ends broadly rounded.
d. Sporocysts not spherical.
e. Sporocyst ovoid or cylindrical.....*Eirmocystis*
ee. Sporocyst prismatic, polygonal in outline.....*Euspora*
dd. Sporocyst spherical or subspherical.....*Uradiophora*
aa. Septum wanting.
f. Sporont globose.....*Sphærocystis*
ff. Sporont elongate .....*Ganymedes*

Frenzelina Leger et Duboscq, *1907,* p. 773-774.

Type—*F. conformis* (Diesing)=*Gregarina conformis* Diesing, *1851,* II, p. 15; from *Pachygrapsus marmoratus* (F.),—*Crustacea.*

Hyalospora A. Schneider, *1875,* 4, p. 583.

Type—*H. roscoviana* A. Schneider, *1875,* 4, p. 584, t.16,f.41-42; from *Petrobius maritimus,—Thysanura.*

Euspora A. Schneider, *1875,* 4, p. 582.

Type—*E. fallax* A. Schneider, *1875,* 4, p. 583, t.18,f.14-17; from *Rhizotrogus æstivus,—Coleoptera.*

Euspora lucani Crawley. Fig. 1.

Euspora lucani Crawley, *1903a,* p. 50-51, pl. III,f.38; Swarthmore, Pennsylvania, from *Lucanus dama* Thunb.—*Coleoptera.*

Epimerite undescribed; elongate and cylindrical, protomerite and deutomerite both broadly rounded; size as given by Crawley, l.c., primite 520μx 128μ, satellite 360μx108μ; cysts unknown. This species is referred to the genus *Euspora* because of the shape of the sporont and the coleopteran host, making the generic determination very uncertain.

Eirmocystis Leger, *1892,* p.110.

Type—*E. ventricosa* Leger,*1892,* p. 111, t.6,f.1-4; from *Tipula oleracea* and *Tipula pratensis* larvæ,—*Diptera.*

Uradiophora Mercier, *1912,* p. 198.

Type—*U. cuenoti* (Mercier)=*Cephaloidophora cuenoti* Mercier, *1911,* p. 51; from *Atyæphyra desmaresti* Millet,—*Crustacea.*

Ganymedes J. Huxley, *1910,* p. 169.

Type—*G. anaspidis* J. Huxley, *1910,* p. 155-175, pl. 11, f. 1-19; from *Anaspides tasmaniæ* (Thompson),—*Crustacea.*

This genus is placed here provisionally because of the similarity of *Ganymedes anaspidis* and *Uradiophora cuenoti* in several features of morphology and in type of host. Since the complete life cycle of *Ganymedes* has not been worked out this arrangement cannot be verified at present.

Sphærocystis Leger, *1892*, p. 115.

Type—*S. simplex* Leger, *1892*, p. 115, t. 6, f. 11-13; from *Cyphon pallidus* larvæ,—*Coleoptera*.

Gregarinidæ

Cysts spherical or ovoid, covered by a gelatinous envelope which is often double; one or more sporoducts forming during maturation, through which the sporocysts are discharged; sporocysts often in chains. As here defined this family includes but part of the species of *Gregarinidae* of authors, the other genera being referred to *Hyalosporidae*. Two of the three genera are represented in the new world fauna.

a. Septum present; protomerite and deutomerite distinct.
b. Sporoducts several.....*Gregarina*
bb. Sporoduct one, large.....*Gigaductus*
aa. Septum wanting .....*Gamocystis*

Gregarina Dufour, *1828*, p. 366.

Type—*G. ovata* Dufour, *1828*, p. 366; from *Forficula auricularia* L.,—*Orthoptera* (*Euplexoptera*).

Of the twenty species from the new world assigned to the this genus the generic determination of but six is absolute, since the dehiscence of the cysts has not been described for the other fourteen. It has been the custom of authors to refer any gregarine found in association to this genus when the data were insufficient for complete determination; hence a large number of species have been placed here tentatively.

Gregarina blattarum Siebold. Figs. 20-22.

Gregarina blattarum Siebold, *1839*, s.57,t.3: Crawley, *1903a*, p. 44; from *Periplaneta orientalis* and *Ectobia germanica*: Hall, *1907*, p. 1; Lincoln, Nebraska, from *Periplaneta americana*: Ellis, *1913c*, p. 83; Douglas Lake, Michigan from Ischnoptera pennsylvanica.

Gregarina blattæ-orientalis Leidy, *1853*, 239, pl. 11, f.11-12; from *Blatta orientalis*.

Clepsidrina blattarum, Magalhæs, *1900*, p. 38-44; Brazil, from *Periplaneta americana* and *Periplaneta orientalis*.

Epimerite short, digitiform to subglobose, about one-half the length of the protomerite of the cephalont; sporont short and broad, both protomerite and deutomerite broadly rounded; average P. 100μx120μ, D. 130μx 400μ; cysts prolate spheroids, average 450μx900μ with gelatinous envelope; sporoducts 10 or more, reaching the length of 200μ; sporocysts barrel-shape, 4μx8μ.

Gregarina panchlorœ Frenzel. Fig. 9.

Gregarina panchlorœ Frenzel, *1892*, s .209, f. 20; Cordoba, Argentine Republic, from *Panchlora exoleta* Klug.

Epimerite undescribed; sporont cylindrical, length 180μ, width 30-35μ; cysts and sporozoites unknown. In associations the protomerite of the satellite is deeply concave at the anterior end to receive the posterior end of the deutomerite of the primite. From the measurements given by Frenzel, a completion of his figure 20 would make the deutomerite about six times as long as the protomerite. This gregarine may be a synonym of the following species. Specimens of *Panchlora* sp. from Quirigua, Guatemala, and from bananas shipped into Boulder, Colorado, were examined by the writer in 1912 but no gregarines found.

Gregarina blaberæ Frenelzel. Fig. 2.

Gregarina blaberæ Frenzel, *1892,* s. 300-314, f.21-33; Cordoba, Argentine Republic, from *Blabera claraziana* and related forms.

Epimerite long, tapering, shaped like a spear-head, enlarged at the base, about twice the length of the protomerite of a large cephalont; sporont elongate, protomerite and deutomerite both broadly rounded; adult sporont 150μx500μ, protomerite about one-fourth the length of the deutomerite; cysts and sporozoites unknown. A specimen of *Blabera* sp. from Gualan, Guatemala contained no gregarines.

Gregarina serpentula Magalhæs. Fig. 3.

Gregarina serpentula Magalhæs, *1900,* p. 40, f.4; Brazil, from *Periplaneta americana.*

Epimerite unknown; sporont elongate, 180μx1200μ, protomerite 50μ in length; cysts undescribed. From the figures given by Magalhæs and Frenzel it seems quite probable that *G. serpentula* is a synonym of *G. blaberæ,* leaving but two species of gregarines known from the roaches of the world at present.

Gregarina achetæ-abbreviatæ Leidy. Fig. 5.

Gregarina achetæ-abbreviatæ Leidy, in part, *1853,* p. 238, pl.11,f.34: Crawley, *1903a,* p. 45, pl.III, f. 35; Beach Haven, New Jersey, from *Acheta abbreviata*: idem, *1903b,* p. 639-641; idem, *1907,* p. 220, pl. XVIII, f. 1; Beach Haven, New Jersey, and Wyncote, Pennsylvania, from *Gryllus abbreviatus.*

Epimerite undescribed; sporont short and broad, protomerite almost spherical, deutomerite rounded posteriorly; average P. 200μx150μ, D. 225μx300μ; cysts spherical, about 250μ, with a gelatinous envelope; sporoducts 2 to 5, elongate, reaching the length 1000μ, (Crawley, 1907, l.c.), sporocysts cylindrical, tapering slightly at each end, ends broadly rounded, 4.5μx2.3μ. Taken by the writer at Douglas Lake, Michigan, July, 1913, from *Gryllus americanus.*

Gregarina longiducta Ellis. Figs. 26-29.

Gregarina longiducta Ellis, *1913c,* p. 78-82, f. 1-8; Douglas Lake, Michigan, from *Ceuthophilus latens* and *Ceuthophilus maculatus.*

Epimerite short and digitiform, about equalling the protomerite of a cephalont in length; sporont short and broad; average P. 200μx170μ, D. 200μx

230μ; cysts spherical with a gelatinous envelope, 200μ to 300μ; sporoducts four or rarely five, at one pole, length when everted enormous, reaching 3500μ; sporocysts barrel-shaped, hexagonal in profile, with rounded edges, 3μx6.5μ. A species much like *G. achetæ-abbreviatæ* from which it differs in the size of the sporocysts, the enormously long sporoducts, and the polar arrangement of the sporoducts.

Gregarina consobrina sp.. nov. Figs. 23-25.

Epimerite short, simple and digitiform, its length about one-third that of the protomerite of the cephalont; sporont short and globose; protomerite hemispherical, not as wide as the deutomerite; length of the protomerite amout one-half of its width and one-fifth of the total length; deutomerite broadly oval in outline, its maximum width about equalling its length; cysts spherical, with a thick, outer, gelatinous envelope and a thin, dense, inner envelope, average cysts 250μ to 300μ; sporoducts four to six in number, all in one hemisphere, very long, averaging 900μ to 1200μ in length; sporocysts cylindrical, slightly rounded at each end, in chains when first discharged, 3.2μx8μ; maturation period in water at room temperature during October, six days or more; average sporonts 600μ in length, P. 130μx300μ, D. 470μx450μ; host, *Ceuthophilus valgus* Scudder, (det. Prof. T. D. A. Cockerell), collected in Boulder Canon, near Boulder, Colorado, at an altitude of about 6,500 feet, October 5, 1913.

This species, *G. achetæ-abbreviatæ* Leidy, and *G. longiducta* Ellis are to be regarded as a species group since they are so closely related yet each presents a different combination of characters. *G. consobrina* Ellis differs from *G. longiducta* Ellis in the position of the sporoducts, these being all in one hemisphere although not closely grouped about the pole; in the length of the sporoducts, which are about one-third as long as those of the latter; and in the shape of the sporont, this being much more globose and the protomerite less distinct. From *G. achetæ-abbreviatæ* Leidy *G. consobrina* differs in shape of sporont, size of sporocyst, lack of orange color in cyst, as well as type of host.

Gregarina rigida (Hall). Fig. 13.

Hirmocystis rigida Hall, *1907*, p.1-26, f. 1-11, 21; Lincoln, Nebraska, from *Melanoplus differentialis, M. femur-rubrum, M. atlantis,* Canon City, Colorado, from *M. bivittatus, M. differentialis, M. angustipennis*: Hall *1912*, p. 337; Canon City, Colorado, from *M. coloradensis,* Boulder, Colorado, Colorado Springs, Colorado, Bethesda, Maryland: Ellis, *1913a*, p. 464; Boulder, Colorado, from *Brachystola magna.*

Gregarina melanopli Crawley, *1907*, p. 223, pl. XVIII, f. 6-9; Wyncote, Pennsylvania from *Melanoplus femoratus*: Ellis, *1913c*, p. 82-83; Douglas Lake, Michigan, from *Melanoplus luridus, M. femur-rubrum; M. bivittatus.*

Epimerite short and digitiform; sporont short and broad, both protomerite and deutomerite rounded, average P. 130μx150μ, D. 140μx570μ; cysts spherical, 300μ to 400μ, covered by a gelatinous envelope,

20μ to 200μ, usually orange in color; sporoducts 10 or more, exceeding the gelatinous envelope but a short distance; sporocysts in chains when first discharged, hyaline, barrel-shaped, rather hexagonal in outline, 5μx8μ; both cysts and sporonts are usually yellow or even orange in color and the sporoduct-buds a brilliant orange just before the sporoducts are everted. This is the common gregarine of North American grasshoppers. Some little confusion concerning the name of this species has arisen as the result of the almost simultaneous publication of the descriptions of *Hirmocystis rigida* Hall and *Gregarina melanopi* Crawley, here considered as synomymous. The original diagnoses of both species were without descriptions of the cysts and their dehiscence. Hall pointed out (1912, p. 337) that the two species were to be regarded as synonyms. The writer, (1913c) described the cysts and their dehiscence for *G. melanopi* Crawley from material collected at Douglas Lake, Michigan, and since returning to Colorado has found the cysts of *Hirmocystis rigida* Hall to dehisce by sporoducts in the same manner; hence the name must stand *Gregarina rigida* (Hall).

Gregarina locustæ-carolinæ Leidy. Fig. 19.

Gregarina locustæ-carolinæ Leidy, in part, *1853*, p. 239, pl. 11, f. 35-38; *Locusta carolina* L.: Crawley, *1907*, p. 225, pl. XVIII, f. 13; from *Dissosteira carolina* (L.), Wyncote, Pennsylvania.

Stephanophora locustæ-carolinæ, Crawley, *1903a*, p. 54, in part.

Epimerite globose, about half the length of the protomerite of the cephalont; sporont short and rounded, protomerite subglobose, deutomerite oval; largest individual seen (Crawley, 1907, p. 225), 350μ; cysts and dehiscence undescribed.

Gregarina passalicornuti Leidy. Figs. 12 and 16.

Gregarina passalicornuti Leidy, *1853*, p. 238, pl. 11, Fig. 30-31: Ellis, *1913b*; New Orleans, Louisiana, from *Passalus cornutus* Fab.

Epimerite undescribed; sporont distinctly longer than broad, rather cylindrical in outline, protomerite hemispherical, deutomerite cylindrical, usually narrowed near the middle; average P. 60μx50μ, D. 60μx 150μ; cysts and sporocysts unknown.

Gregarina guatemalensis Ellis. Fig. 15.

Gregarina guatemalensis Ellis, *1912c*, p. 687, Fig. 6; Quirigua, Guatemala, from *Nelus interstitialis*

Epimerite undescribed; sporont short and broad, especially in the posterior portion of the deutomerite; protomerite subglobose; deutomerite cylindrical, widening rather abruptly near its posterior end; average P. 70μx 80μ, D. 160μx180μ; cysts and dehiscence undescribed.

Gregarina xylopini Crawley. Fig. 17.

Gregarina xylopini Crawley, in part, 1903a, p. 47, pl. III, f. 30; from *Xylopinus saperdioides*.

Epimerite undescribed; sporont somewhat elongate; protomerite elongate, distinctly narrowed near the middle, its length twice its width; pro-

tomerite cylindrical, its width about one-third its length; cysts and dehiscence undescribed; size not given in original diagnosis.

Gregarina grisea Ellis. Fig. 18.

Gregarina grisea Ellis, *1913b*, p. 200, f. 1; New Orleans, Louisiana, from *Tenebrio castaneus* Knoch.

Epimerite undescribed; sporont short and ovoid; protomerite hemispherical, narrower than the deutomerite; deutomerite oval, its posterior margin broadly rounded; average P. 60μx50μ, D. 100μx370μ.

Gregarina microcephala Leidy.

Gregarina microcephala Leidy, *1889*, p. 11, 1 Fig.; from *Hoplocephala bicornis*.

This is known only from the original diagnosis. Since its position is very uncertain Leidy's description is copied here.

"In some little green beetles, *Hoplocephala bicornis*, one of the Tenebrionidæ, I found a number of gregarines remarkable for the small size of the head and hence the species may be named *Gregarina microcephala*. The body is clavate; the head like a watch crystal with a little ball at the summit. Length 0.35 mm. by 0.1 wide; head 0.012 long by 0.04 wide. It bears a close resemblance to *Echinocephalus hispidus* of Schneider, found in *Lithobius forcipatus*, but in the one described I at no time found digitiform appendages to the head."

The host of this species is now known as *Arrhenoplita bicornis* (Olivier).

Gregarina scarabeirelicti Leidy.

Gregarina sp. Leidy, *1851a*, p. 208; from the larvæ of a large lamellicorn insect.

Gregarina scarabeirelicti Leidy, *1851b*, p. 287; from larvæ of *Scarabeus relictus*.

This species and the following one, *G. melalonthæbrunneæ* Leidy, are known only from the original diagnoses, which are incomplete and without figures. Until these species are redescribed their position and validity are doubtful. Leidy's diagnoses are copied here.

"Body white, cylindro-fusiform. Superior division presenting four sides of a hexagon, subacute. Nuclear body of inferior division transparent, globular or elliptical, containing several coarse granules. Length from 1-66th to 1.25 lines; head 1-400th inch to 1-133d inch long by 1-285th inch to 1-111th inch broad. Anterior portion of inferior division 1-200th inch to 1-86th inch broad; posterior portion 1-666th to 1-250th inch broad. —".

Gregarina melalonthæbrunneæ Leidy.

Gregarina melalonthæbrunneæ Leidy, *1856*, p. 47; from *Melalonthabrunnea*.

"Body oblong oval; head oblate spheroidal, slightly elevated at the summit. Single and in pairs. Length of body .405 mm., breadth .252 mm.; length of head .108 mm., breadth .144 mm."

Gregarina statiræ Frenzel. Fig. 14.

Gregarina statiræ Frenzel, *1892*, p. 234-286, t. VIII, f. 1-15; Cordoba, Ar-

gentine Republic, from *Statira unicolor* Blanch.

Epimerite short, simple, conic; cephalonts and free sporonts ovoid; sporonts in association globose; protomerite hemispherical to subglobose, its length about one-fourth of the total length, width of the protomerite less than that of the deutomerite, in large sporonts about one-half the width of the deutomerite; protomerite of satellite quite compressed; cysts and sporocysts unknown; large sporonts 300μx350μ.

Gregarina bergi Frenzel. Figs. 38-39.

Gregarina bergi Frenzel, *1892*, p. 286-298, f. 16-19; Cordoba, Argentine Republic, from *Corynetes ruficollis.*

Epimerite simple, styliform, enlarged near the base so that it is arrow-head-shaped in profile, its length greater than that of the protomerite of the cephalont, its greatest width about one-half that of the protomerite; sporonts ovoid; protomerite hemispherical, almost as wide as the deutomerite, length of the protomerite about one-fourth of the total length; posterior margin of the deutomerite broadly rounded; cysts and sporocysts unknown; average individuals 90μx300μ. This gregarine has been taken by Wellmer, 1912, in Prussia from *Corynetes violaceus* L. He reports it as forming associations.

Gregarina elateræ Crawley. Fig. 10-11.

Gregarina elateræ Crawley, *1903a*, p. 46, pl. I, f.11; Wyncote, Pennsylvania, from *Elater* sp. larvæ.

Hirmocystis ovalis Crawley, *1903a*, p. 50, pl. I, f. 5-6; from larvæ of beetles, doubtfully identified as *Cucujidæ.*

Epimerite globose to ovoid, almost equalling the length of the protomerite of the cephalont in diameter; cephalont ovoid; sporont rather cylindrical, both protomerite and deutomerite broadly rounded; protomerite hemispherical about one-fourth as long as the deutomerite; deutomerite cylindrical, a little broader at its junction with the protomerite than the protomerite; cysts and sporocysts undescribed; no associations observed; maximum length as given by Crawley, 70μ.

Gregarina termitis Leidy. Fig. 6.

Gregarina termitis Leidy, *1881*, p. 441, pl. 52, f. 27: Porter, *1897*, p. 65, pl. 6, f. 73-76; Cambridge, Mass. from *Termes flavipes.*

Epimerite undescribed; sporont short, distinctly longer than broad, protomerite oval to subglobose, deutomerite ovoid to cylindrical; average P. 25μx170μ, D. 30μx400μ, cysts and sporocysts unknown. The writer has taken this species at Boulder, Colorado from *Termes lucifugus* during 1912 and 1913.

Gregarina calverti Crawley. Fig. 4.

Gregarina calverti Crawley, *1903a*, p. 48, pl. II, f. 19-21; Wyncote, Pennsylvania, from *Lysiopetalum lactarium;* idem. *1903b*, p. 638, pl. XXX, f.15.

Epimerite undescribed; sporont elongate and cylindrical, protomerite short, oval in outline, about one-twentieth as long as the deutomerite, somewhat more globose in young sporonts equalling about one-sixth of the length

of the deutomerite, deutomerite elongate and cylindrical, tapering posteriorly in young sporonts; cysts spherical, about 300μ in diameter; sporocysts barrel-shaped, 5μx13μ; average sporonts 1000μ.

Gregarina sp.

Gregarina sp. Ritter, Proc., Cal. Acad. Sci., ser. 2, 4, p. 39-85, 1893. This description was not seen by the writer.

Gigaductus Crawley, *1903a*, p. 633.

Type—*G. parvus* Crawley, *1903a*, p. 633, pl. XXX, f. 10-13; from *Harpalus caliginosus* Fab.,—*Coleoptera.*

Gigaductus parvus Crawley. Fig. 8.

Gigaductus parvus Crawley, *1903a*, p. 633, pl. XXX, f. 10-13; Wyncote, Pennsylvania fram *Harpalus caliginosus* Fab.: Ellis, 1913a, p. 465; Vincennes, Indiana, from *Harpalus pennsylvanicus* Dej.

Epimerite undescribed; sporont longer than wide though not greatly elongate, oval in outline with a distinct constriction at the junction of the protomerite and deutomerite; protomerite subglobose; deutomerite ovoid, tapering noticeably toward the posterior end; average P. 70μx45μ, D. 80μx160μ; cysts spherical, about 200μ in diameter, dehiscence by one, large, short sporoduct; sporocysts cylindrical, 25μx12μ.

Gigaductus kingi (Crawley). Fig. 7.

Gregarina kingi Crawley, *1907*, p. 221, pl. XVIII, f. 10-12; from *Gryllus abbreviatus* Serv.

Epimerite undescribed; sporont longer than wide; protomerite of primite knob-shaped, widest in its anterior half, deeply constricted near the middle; protomerite of the satellite subglobose; deutomerite oval in outline; average P. 60μx40μ, D 60μx120μ; cysts spherical or oval, about 100μ in diameter, dehiscence by one large, rather long sporoduct; sporocysts barrel-shaped, 3μx5μ.

Gamocystis A. Schneider, *1875*, p. 587.

Type—*G. tenax* A. Schneider, *1875*, p. 587, t. 19, f. 10-13, t.21,f.6; from *Ectobia lapponica* (L.),—*Orthoptera.*

This genus is without a known representative in our fauna at present.

Actinocephalidæ

Dehiscence of cysts by simple rupture; sporocysts biconic or navicular to crescentic; epimerite variable; sporonts not forming associations. As here defined this family includes both the *Actinocephalidæ* and *Menosporidæ* of Leger. The epimerite becomes highly specialized in some species of this family, yet the entire gamut of possibilities is run from the simple to the extremely elaborate. Three types are represented if typical species be chosen: (1) epimerite simple and styliform—*Stylocystis;* (2) styliform with a circular, elevated and divided, basal portion—*Pyxinia;* (3) epimerite

consisting of a circular elevated and divided portion, with a central concavity, suggestive of the disappearance of the styliform portion of the other two types—*Menospora*. An effort to divide the family according to these three types of epimerite is unsatisfactory, however, since the various combinations of these epimerite characters, as regards presence and absence, and degree, intergrade. A key to the genera, although perhaps somewhat artificial, is possible on epimerite characters.

a. Protomerite regular, not divided.
  b. Epimerite simple.
    c. Epimerite rounded, -hemispherical; protomerite of the cephalont much compressed and elevated around the base of the epimerite like a collar.....*Amphoroides*
    cc. Epimerite styliform.
      d. Epimerite at first short and styliform, but becoming rounded and button-shaped as the cephalont develops ..... *Steinina*
      dd. Epimerite not becoming button-shaped.
        e. Epimerite simple styliform, often curved.*Stylocystis*
        ee. Epimerite conical, arrowhead-shaped in profile.... ..... *Pileocephalus*
  bb. Epimerite not simple.
    f. Carried by a much produced portion of the protomerite.
      g. With retrose spine-like processes; styliform to subglobose ..... *Geniorhynchus*
      gg. Without retrose spine-like processes.
        h. Apical portion with digitiform processes.
          i. Apex concave, with a marginal row of recurved processes.....*Menospora*
          ii. Apex convex, with six to eight marginal digitiform processes.....*Hoplorhynchus*
        hh. Without apical digitiform processes; a rounded marginal portion in the center of which is an elevated cup-shaped portion with a scalloped edge; central portion evertible.....*Phialoides*
    ff. Anterior portion of the protomerite of the cephalont slightly if at all produced.
      j. Septum wanting; epimerite disk-shaped to subglobose, its margin scalloped deeply.....*Schneideria*
      jj. Septum present, protomerite and deutomerite distinct.
        k. Epimerite consisting of a central elevated portion surrounded at its base by a marginal elevated or divided portion.

l. Central portion rounded, hemispherical, marginal portion rounded and undivided..... ..... *Discorhynchus*

ll. Central portion pointed and styliform.

m. Basal portion scalloped.....*Pyxinia*

mm. Basal portion subglobose, produced into horizontal or slightly recurved teeth.... ..... *Beloides*

kk. Epimerite without a central elevated portion.

n. Deutomerite not divided by septa.

o. Epimerite short, with a series of long hair-like filaments.....*Bothriopsis* ..... *Coleorhynchus* ..... *Legeria*

oo. Epimerite without long filaments but with short digitiform processes.

p. Basal portion of the epimerite longer than the digitiform processes, cylindrical to flask-shaped..... ..... *Amphorcephalus*

pp. Basal portion equal to or shorter than the digitiform processes.

q. Digitiform processes free and well separated ...*Actinocephalus*

qq. Digitiform processes placed close together, more or less united at the base .....*Stephanophora*

ooo. Epimerite without long filaments, consisting of button-shaped or subglobose mass deeply fluted.

r. Basal portion of the lobes rounded.. ..... *Anthorhynchus*

rr. Basal portion of the lobes pointed and recurved .....*Stictospora*

nn. Deutomerite divided by several septa; epimerite subglobose with recurved hooks..... ..... *Tæniocystis*

aa. Protomerite produced and divided equatorially so that the whole has somewhat the appearance of half-raised umbrella; epimerite consisting of a circular series of short digitiform processes carried on a narrowed portion of the protomerite....*Sciadiophora*

Amphoroides Labbe, *1899,* p. 20.

Amphorella Leger, *1892,* p. 132. Preoccupied.

Type—*A. polydesmi* (Leger)=*Amphorella polydesmi* Leger, *1892,* p. 132, t.10,f.9-14; from *Polydesmus complanatus* (L.),—Diplopoda.

Amphoroides polydesmivirginiensis (Leidy). Fig. 36.

Gregarina polydesmivirginiensis Leidy, *1853,* p. 238, pl. 10, f.23-29; *Amphoroides polydesmivirginiensis,* Crawley, *1903a,* p. 45,pl.II,f.25; Wyncote, Pennsylvania and Raleigh, North Carolina, from *Polydesmus virginiensis.*

Epimerite undescribed; protomerite button-shaped to subglobose, small, and narrower than the deutomerite, greatest length of the protomerite not exceeding one-tenth of the length of the deutomerite; deutomerite elongate, rounded posteriorly, widened in the anterior half; epicyte thick; cysts and sporocysts unknown; average sporonts 400μ.

Amphoroides fontariæ Crawley. Fig. 37.

Amphoroides fontariæ Crawley, *1903a,* p. 53, pl. I, f.12-14; Wyncote, Pennsylvania, and Raleigh, North Carolina, from *Polydesmus* sp. and *Fontaria* sp.

Epimerite undescribed; sporont somewhat ovoid in shape, protomerite subglobose, its maximum width less than that of the deutomerite, its length one-fourth or less of the length of the deutomerite; deutomerite oval in outline, often widened in its anterior half; average sporonts about 170μ; sporocysts and cysts unknown. The writer has taken this species from specimens of *Polydesmus sp.* collected by Mr. S. A. Rohwer at East Falls Church, Virginia, in May, 1913.

Steinina Leger et Duboscq, *1904,* p. 352.

Type—*S. ovalis* (Stein)=*Stylorhynchus ovalis* Stein, *1848,* p. 182-223; from *Tenebrio molitor* L. larvæ—*Coleoptera.*

This species, *S. ovalis* (Stein), or others of the same genus, should be looked for in North America since the host and other closely related species are found in our fauna.

Stylocystis Leger, *1899,* p. 526.

Type—*S. præcox* Leger, *1899,* p. 526-533; from *Tanypus* sp. larvæ—*Coleoptera.*

Stylocystis ensiferus (Ellis). Fig. 34.

Stylocephalus ensiferus Ellis, *1912c,* p. 686, f.5; Quirigua, Guatemala, from *Leptochirus edax* Sharp.

Epimerite simple and styliform, its length about equal to that of the protomerite of the cephalont; sporont ovoid, the deutomerite broadly rounded posteriorly, protomerite subglobose, deutomerite cylindrical; average sporonts 50μ; cysts and sporocysts unknown.

Pileocephalus A. Schneider, *1875,* p. 591.

Type—*P. chinensis* A. Schneider, *1875,* p. 592, t.16,f.21-24; from *Mystacides* sp. larvæ—*Trichoptera.*

Geniorhynchus A. Schneider, *1875,* p. 594.

Type—*G. monnieri* A. Schneider, 1875, p. 595, t.20,f.21-27; from *Libellula* sp. nymphs—*Odonata.*

Geniorhynchus æshnæ Crawley. Fig. 41.

Geniorhynchus æshnæ Crawley, *1907*, p. 227, pl. XVIII, f.4; Southeastern Pennsylvania, from nymphs of *Aeshna constricta* Say.

Epimerite subglobose, carried by an elongated portion of the protomerits, with numerous short, spine-like processes directed posteriorly; both protomerite and deutomerite resembling truncated cones with their bases together; deutomerite according to Crawley often constricted posteriorly; size given as 420μ; cysts and sporocysts not known.

Menospora Leger, *1892*, p. 151.

Type—*M. polyacantha* Leger, *1892*, p. 151, t.19,f.1-5; from *Agrion puella* (L.) nymphs—*Odonata*.

Hoplorhynchus Carus, *1863*, p. 570.

Type—*H. oligacanthus* (Siebold)=*Gregarina oligacantha* Siebold, 1839, t.3; from *Calopteryx virgo* (L.)—*Odonata*.

Phialoides Labbe, *1899*, p. 24.

Phialis Leger, *1892*, p. 135. Preoccupied.

Type—*P. ornata* (Leger)=*Phialis ornata* Leger, 1892, p. 135,t.13,f.4-12; from *Hydrophilus piceus* (L.) larvæ—*Coleoptera*.

Schneideria Leger, *1892*, p. 153.

Type—*S. mucronata* Leger, *1892*, p. 153, t.2,f.7-13; from *Bibio marci* (L.) larvæ—*Diptera*.

Discorhynchus Labbe, *1899*, p. 20.

Discocephalus Leger, *1892*, p. 134. Preoccupied.

Type—*D. truncatus* (Leger)=*Discocephalus truncatus* Leger, *1892*, p. 134, t.15,f.10-12; from *Sericostoma* sp. larvæ—*Trichoptera*.

Pyxinia Hammerschmidt, *1838* p. 35.

Asterophora Leger, *1892*, p. 129.

Type—*P. rubecula* Hammerschmidt, *1838*, p. 357, t.4,f. a-g; from *Dermestes lardarius* L.—*Coleoptera*.

Pyxinia crystalligera Frenzel. Fig. 43-44.

Pyxinia crysatlligera Frenzel, *1892*, p. 314-332, f. 34-50; Cordoba, Argentine Republic, from *Dermestes vulpinus* Fab. and *Dermestes peruvianus* Castelnau, and larvæ of the latter.

Epimerite consisting of a circular basal portion with a fluted margin and a central styliform portion, the length of the styliform portion exceeding one-half the length of the protomerite of the cephalont; sporont somewhat elongate, protomerite globose, narrower than the widest portion of the deutomerite, deutomerite broad just posterior to the protomerite; average sporonts 90μx250μ.

Beloides Labbe, *1899*, p. 26.

Xiphorhynchus Leger, *1892*, p. 137. Preoccupied.

Type—*B. firmus* (Leger)=*Xiphorhynchus firmus* Leger, 1892, p. 138, t.17, f.1-4; from *Dermestes lardarius* L.—*Coleoptera*.

Bothriopsis A. Schneider, *1875*, p. 596.

Type—*B. histrio* A. Schneider, *1875*, p. 596, pl. XXI, f.8-13; from *Hydaticus cinereus*,—*Coleoptera*.

Bothriopsis histrio A. Schneider. Fig. 42.

Bothriopsis histrio Schneider, *1875*, p. 596, pl. XXI, f.8-13; Crawley, *1903a*, p. 54-55, pl. II, f.15-18; Wyncote, Pennsylvania, from *Hydaticus cinereus* larvæ, *Colymbetes fuscus* and *Acilius sulcatus*.

Epimerite consisting of a short button-shaped portion from the margin of which are six or more long hair-like filaments; protomerite of the cephalont subglobose anteriorly and cylindrical posteriorly; deutomerite of cephalont ovoid; sporont variable and very active changing shape readily, in expanded individuals the protomerite is subglobose with a cup-shaped depression posteriorly into which the conical anterior end of the deutomerite fits, deutomerite, aside from the portion included by the protomerite, elongate and conical; sporonts reach the length of 500μ; cysts spherical, about 400μ in diameter, dehiscing by simple rupture; sporocysts biconic, 5μx7μ.

Coleorhynchus Labbe, *1899*, p. 23.

Coleophora A. Schneider, *1885*, p. 94. Preoccupied.

Type—*C. heros* (A. Schneider)=*Coleophora heros* A Schneider, *1885*, p. 95, t.25; from *Nepa cinerea* L.—*Hemiptera*.

Although the type of epimerite for this genus has not been described it is placed in the key with *Bothriopsis* because of the aquatic host.

Legeria Labbe, *1899*, p. 24.

Dufouria A. Schneider, *1875*, p. 595. Preoccupied.

Type—*L. agilis* (A. Schneider)=*Dufouria agilis* A. Schneider, 1875, p. 595, t.22, f.1-6; from *Colymbetes* sp. larvæ—*Coleoptera*.

Legeria terpsichorella sp. nov. Fig. 30.

Epimerite not seen; sporonts extremely active constantly changing the shape of the anterior three-fifths of the body and proceeding rather rapidly in a serpentine path as a result, the protomerite often being bent almost forty-five degrees from the main axis of the body; expanded individual with a protomerite equal to or longer than the deutomerite, the anterior fourth of the protomerite hemispherical to subglobose, below which is an elevated flange-like portion, remaining two-thirds cylindrical, the posterior portion with a cup-shaped depression some 60μ deep into which the anterior conical portion of the deutomerite fits; deutomerite excepting the portion included by the protomerite ovoid, rather sharply rounded posteriorly; average sporonts about 720μ in length; length of the deutomerite to the external junction with protomerite 320μ, of the anterior conical portion of the deutomerite 96μ, of the protomerite to the flange portion 320μ, from flange to anterior end 80μ; width of deutomerite 145μ, of the flange portion of the protomerite 175μ; epicyte thin and flexible; sarcocyte scarcely visible; nucleus seen only with the use of reagents; endocyte dense and homogeneous, of a light brown color; cysts and sporocysts not seen.

Host, *Hydrophilus* sp., Douglas Lake, Michigan, July, 1913.

Amphorellus Ellis, *1913a*, p. 462.

Type—*A. amphorellus* Ellis, *1913a,* p. 463, f. 1-2; from *Scolopendra heros* Girard—*Chilopoda.*

Amphorocephalus amphorellus Ellis. Figs. 51-52

Amphorocephalus amphorellus Ellis, *1913a,* p. 463, f. 1-2; Boulder, Colorado, from *Scolopendra heros* Girard.

Epimerite flask-shaped with a marginal row of small digitiform processes at its anterior end, its length greater than that of the protomerite of the cephalont; protomerite with a constriction near the middle; deutomerite of the cephalont elongate and conical, broadest near its anterior end, where its maximum width is twice that of the protomerite; deutomerite of the sporont elongate and cylindrical, rather sharply and abruptly pointed at its posterior end; sporonts reaching the length of 1,000μ; P. 60μx50μ, D. 60μx950μ; cysts unknown.

Amphorocephalus actinotus (Leidy). Fig. 53.

Gregarina actinota Leidy, *1889,* p. 10, f.1; from *Scolopocryptops sexspinosus.*

Hoplorhynchus actinotus, Crawley, *1903a,* p. 55, pl. III, f.36-37; Wyncote, Pennsylvania, Raleigh, North Carolina, and Wallingford, Pennsylvania, from *Scolopocryptops* sp.

Hoplorhynchus scolopendras Crawley, *1903b,* p. 636, pl. XXX, f.19; Raleigh, N. C. from *Scolopendra woodi* Meiner.

Epimerite elongate, flask-shaped, bearing at its anterior end a series of small digitiform processes carried by four horizontal lobes, length of the epimerite equal to from one-half to one fourth of the total length of the cephalont; protomerite hemispherical to subglobose; deutomerite elongate, conical and pointed posteriorly, its maximum width about one-third of its length; size, as given by Leidy 600μ for the cephalont, by Crawley, 485μ for the sporont; cysts unknown.

Actinocephalus F. Stein, 1848, p. 196.

Stephanophora Leger, *1892,* p. 127.

Type—*A. lucani* F. Stein, *1848,* t. 9, f. 33; from Lucanid beetle.

It is to be noted that *Stephanophora* Leger, was invalid since it included the single species *Actinocephalus lucani* Stein (redescribed by Leger as *Stephanophora radiosa* Leger), the type of Stein's genus *Actinocephalus.* Leger, *1892,* recognized the synonomy of *Actinocephalus lucani* Stein with his species *Stephanophora radiosa,* but by its removal from the genus of Stein (wrongly ascribed to Schneider by Leger, 1892, p. 141), the genus *Actinocephalus* Stein was left without a species included in its original description. This situation renders the name *Actinocephalus* as restricted by Leger, l. c., and Labbe, (*1899,* p. 25), invalid. In restoring the name *Actinocephalus* to its type *A. lucani* Stein, *Actinocephalus* of authors stands without a name. Since *Stephanophora* Leger and *Actinocephalus* of authors are so closely related it seems best to consider them synonomous, avoiding

the confusion attendant to the substitution of a new name. Both epimerite and sporocyst characters of *Stephanophora* and *Actinocephalus* intergrade.

Actinocephalus pachydermus (Crawley). Figs. 54-55.

Stephanophora pachyderma Crawley, *1907*, p. 226, pl. XVIII, f. 2-3; Wyncote, Pennsylvania, from *Dissosteira carolina* (L.)

Gregarina locustæ-carolinæ Leidy, in part, *1853*, p. 239, pl. 11, f. 37-38.

Stephanophora locustæ-carolinæ, Crawley, in part, *1903a*, p. 54.

Epimerite subglobose, bearing at its apex a marginal row of digitiform processes; protomerite somewhat hemispherical with the epicyte slightly produced to receive the epimerite; deutomerite of the cephalont elongate but rather broad; sporont oval in outline, protomerite short and hemispherical, its length about one-fourth of the total length; epicyte very thick in both cephalont and sporont; sporonts reaching the length of 500μ; cysts unknown. It seems quite probable that the undescribed gregarine figured by Hall, (*1907*, f. 13) from *Chimarocephalus viridifasciata* taken at Lincoln, Nebraska, was a sporont of this species.

Actinocephalus zophus (Ellis) Fig. 49.

Stephanophora zopha Ellis, *1913b*, p. 201, f. 2; New Orleans, Louisiana, from *Nyctobates barbata* Knoch.

Gregarina xylopini Crawley, in part, *1903a*, p. 47, f. 29; from *Xylopinus saperdioides*.

Epimerite short and subcylindrical, with an apical row of marginal digitiform processes; protomerite subglobose, its diameter equal to or a little greater than the length of the epimerite; deutomerite elongate, cylindrical, pointed posteriorly; sporont elongate and cylindrical, pointed posteriorly, length of the protomerite 8 to 12 in the length of the deutomerite; sporonts reaching length of 1600μ; cysts unknown. The writer has taken this gregarine from specimens of *Alobates pennsylvanicus* deGeer collected at East Falls Church, Virginia in May, 1913 by Mr. S. A. Rohwer.

Actinocephalus crassus (Ellis). Fig. 40.

Stephanophora crassa Ellis, *1912c*, p. 688, f. 7; Quirigua, Guatemala, from *Leptochirus edax* Sharp.

Known only from the sporont; general shape ovoid with the posterior portion of the deutomerite narrowed and conical; protomerite hemispherical, its length equal to about one-third of the total length; deutomerite broad in the anterior half, narrowed rather abruptly in the posterior half to a rounded cone; epicyte thick.

Actinocephalus harpali (Crawley). Fig. 46.

Gregarina harpali Crawley, *1903a*, p. 49-50, pl. I, f. 1-4; Wyncote, Pennsylvania from *Harpalus caliginosus*.

Actinocephalus harpali, Crawley, 1903b, p. 637-638, pl. XXX, f. 14.

Epimerite undescribed; sporont ovoid; protomerite hemispherical its length about one-sixth of the total length and about one-half of its own width; deutomerite ovoid; sporonts reaching the length of 1200μ. Cysts about 500μ in diameter, covered with a thick gelatinous envelope, dehiscing

by simple rupture; sporocysts 7.5μ x 9μ, described by Crawley as, "diamond shaped in longitudinal and hexagonal in transverse section."

Actinocephalus discæli (Crawley). Fig. 50.

Gregarina discæli Crawley, *1903a*, p. 47, pl. I, f. 7-10; Wyncote, Pennsylvania, from *Discælus ovalis*.

Epimerite undescribed; sporont elongate, posterior end of the deutomerite tapering and pointed; protomerite pentagonal in outline, as wide or slightly wider than the deutomerite, its length about one-thirteenth of the total length in large sporonts; cysts and sporocysts unknown. This gregarine is placed in the genus *Actinocephalus* because of the general shape of the sporont and the coleopteran host; it was removed from the genus *Gregarina* since the sporonts do not form associations. The grouping of large numbers of sporonts with the posterior ends of their deutomerites touching can not be considered an association in the sense of a Gregarinid association, and has also been observed for species of *Stylocephalus* and *Actinocephalus*.

Actinocephalus dujardini A. Schneider. Fig. 45.

Actinocephalus dujardini A. Schneider, *1875*, p. 589, pl. 16, f. 9-20; Crawley, *1903a*, p. 55; from *Lithobius forcipatus*.

Epimerite subglobose with a short neck, bearing a marginal row of about twenty short, rigid, recurved, tooth-like processes at its anterior end; protomerite subglobose to cuboidal; its length equal to half or more of the length of the deutomerite; deutomerite rather broad, conical; size small.

Actinocephalus americanus Crawley, Fig. 56.

Actinocephalus americanus Crawley, *1903b*, p. 636, pl. XXX, f. 22; Wyncote, Pennsylvania, from *Galerita bicolor* Drury.

This gregarine was described from a single specimen, 200μ x 45μ, protomerite 35μ long. Crawley states that it is probably "only sporadically present in *Galerita*, and that its usual host is some other animal." There exists but this single record of this species.

Actinocephalus brachydactylus sp. nov. Figs. 31-33.

Epimerite very short, composed of a circular row of eight short digitiform processes united basally; protomerite globose to dome-shaped, in the cephalonts slightly broader than the deutomerite; deutomerite subcylindrical, tapering gradually towards the posterior end which is broadly rounded; average cephalont 320μ in length, protomerite 80μ x 80μ, deutomerite 75μ x 240μ; sporonts reaching the length of 500μ; cysts not seen. Host, nymphs of *Aeshna* sp., Douglas Lake, Michigan. Taken July, 1913.

Anthorhynchus Labbe, *1899*, p. 19.

Anthocephalus A. Schneider, *1887*, p. 69. Preoccupied.

Type—*A. sophiæ* (A. Schneider) = *Anthocephalus sophiæ* A. Schneider, *1887*, p. 69, t. 10, f. 11-17; from *Phalangium opilio L.—Phalangidea*.

Anthorhynchus cratoparis (Crawley). Fig. 47.

Asterophora cratoparis Crawley, *1903a*, p. 54, pl. II, f. 23; Swarthmore, Pennsylvania, from *Cratoparis lunatus*.

Epimerite spherical, deeply fluted, borne by a short elevation from the anterior portion of the protomerite; protomerite subglobose; deutomerite in the form of a truncated cone, somewhat elongate and narrowed at the anterior end where it joins the protomerite; length given as 540μ; cysts undescribed.

Anthorhynchus philicus (Leidy). Fig. 48.

Gregarina philica Leidy, *1889*, p. 9, 1 f.; from *Nyctobates pennsylvanica*. *Asterophora philica*, Crawley, in part, *1903a*, p. 53, pl. III, f. 31-32.

Epimerite spherical, deeply fluted; protomerite subglobose to cuboidal, about one-ninth the length of the deutomerite; deutomerite elongate, subcylindrical, tapering to a point at the posterior end; length as given by Crawley, 300μ; cysts undescribed.

Anthorhynchus boletophagi (Crawley). Fig. 57.

Gregarina boletophagi Crawley, *1903a*, p. 47, pl. II, f. 26-28; Swarthmore, Pennsylvania, from *Boletophagus cornutus*.

Epimerite undescribed; sporont subcylindrical, protomerite oval in outline with a short dome-shaped portion at the anterior end, length of the protomerite a little more than one-fourth of the total length, deutomerite regularly cylindrical excepting the extreme posterior end which tapers rather abruptly so as to form a truncated cone. This species has been transferred to this genus from *Gregarina* although neither cysts nor epimerite are known, because it is not found in association, and because the anterior portion of the protomerite is suggestive of the slightly produced protomerites of other species of the genus *Anthorhynchus*, which bear the epimerites. It is to be regarded as a provisional determination only.

Stictospora Leger, *1893*, p. 117.

Type—*S. provincialis* Leger, *1893*, p. 129-131; from *Melolontha* sp. larvæ —*Coleoptera*.

Tæniocystis Leger, *1906*, p. 307.

Type— *T. mira* Leger, 1906, p. 307-329; from *Ceratopogon solstitialis* Winn., larvæ—*Diptera*.

Sciadiophora Labbe, *1899*, p. 17.

Lycosella Leger, *1896*, p. 36. Preoccupied.

Type—S. phalangii (Leger) = *Lycosella phalangii* Leger, *1896*, p. 36, t. 3, f. 1-15; from *Phalangium crassum* Duf.—*Phalangidea*.

The writer has opened the alimentary canal of perhaps two hundred *Phalangidea* from Douglas Lake, Michigan, and from Boulder, Colorado, without finding any gregarine infection, although *S. phalangii* (Leger) and related species are reported as very abundant in the *Phalangidea* of Europe.

Acanthosporidæ

Dehiscence of cysts by simple rupture; sporocysts with spines; sporonts always solitary. No species referable to this family have

been taken as yet in the new world. The genera may be separated by the following key:

a. Epimerite without lateral recurved processes or long filaments; spines at both the equator and the poles of the sporocysts. *Acanthospora.*

aa. Epimerite with either lateral recurved processes or long filaments.

b. Epimerite with lateral recurved processes.

c. Sporocysts with spines only at the poles.....*Corycella*

cc. Sporocysts with spines at both the equator and poles. *Ancyrophora*

bb. Epimerite with long filaments; sporocysts with spines both at the poles and above and below the equator.....*Cometoides*

Acanthospora Leger, *1892,* p. 145.

Type—*A. pileata* Leger, *1892,* p. 145, t. 15, f. 1-5; from *Omoplus* sp. larvæ—*Coleoptera.*

Corycella Leger, *1892,* p. 144.

Type—*C. armata* Leger, *1892,* p. 144, t. 16, f. 7-12; from *Gyrinus natator* —*Coleoptera.*

Ancyrophora Leger, *1892,* p. 146.

Type—*A. gracilis* Leger, *1892,* p. 146, t. 19, f. 11-13; from *Carabus auratus* L.,—*Coleoptera.*

Cometoides Labbe, *1899,* p. 29.

Pogonites Leger, *1892,* p. 148. Preoccupied.

Type—*C. crinitus* (Leger) = *Pogonites crinitus* Leger, *1892,* p. 149, t. 18; from *Hydrobius* sp. larvæ—*Coleoptera.*

Stylocephalidæ

Dehiscence of cysts by simple rupture with a pseudocyst; sporonts solitary; sporocysts subspherical but asymmetrical, united in chains usually black or dark brown; sporulation distinctly anisogamic. The species of this family are known only from Tenebrionid beetles*

a. Epimerite cup-shaped, composed of a row of short digitiform processes surrounding a membranous portion.....*Lophocephalus*

aa. Epimerite without digitiform processes.

b. Epimerite large and conical, carried by a short neck..... ..... *Cystocephalus*

bb. Epimerite small, carried by a long base.

c. Epimerite spherical or ovoid.....*Sphærorhynchus*

cc. Epimerite cylindrical and pointed, with a bulbous basal portion .....*Stylocephalus*

Lophocephalus Labbe, *1899,* p. 31.

*The species *Stylocephalus caudatus* (Rössler) is probably referable to the genus *Stictospora* of the *Actinocephalidae.* This species is from a Phalangid host.

Lophorhynchus A. Schneider, *1882,* p. 435. Preoccupied.
Type—*L. insignis* (A. Schneider) = *Lophorhynchus insignis* A. Schneider, *1882,* p. 435, t. 13, f. 1-3, 5, 12, 13, 48, 50; from *Helops striatus* Fourc—*Coleoptera.*

Cystocephalus A. Schneider, *1886,* p. 99.
Oocephalus A. Schneider, *1886,* p. 101.
Type—*C. algerianus* A. Schneider, *1886,* p. 100, t. 27, from *Pimelia* sp.—*Coleoptera.*

Sphærorhynchus Labbe, *1899,* p. 32.
Sphærocephalus A. Schneider, *1886,* p. 100, Preoccupied.
Type—*S. ophioides* (A. Schneider) = *Sphærocephalus ophioides* A. Schneider, *1886,* p. 100, t. 28; from *Acis* sp.—*Coleoptera.*

Stylocephalus Ellis, 1912, p. 25.
Stylorhynchus Stein, *1848,* p. 195. Preoccupied.
Type—*S. giganteus* Ellis, *1912,* p. 25-27, f. 1-2; from *Eleodes* sp.—*Coleoptera.*

Stylocephalus giganteus Ellis. Figs. 58-59.
Stylocephalus giganteus Ellis, *1912a,* p. 25-27, f. 1-2; Boulder, Colorado, from *Eleodes* sp.: Hall, 1912, p. 337-338; Amo, Colorado, from *Eleodes hispilabris* and *Eleodes* sp.

Epimerite rather styliform, basal bulbous portion less than half as long as the distal cylindrical portion; collar joining the epimerite to the protomerite almost, if not quite as long, as the epimerite proper and exceeding it in diameter; epimerite and collar exceeding the length of the protomerite of the cephalont; sporont greatly elongate, sub-cylindrical, pointed posteriorly; sporonts exceeding 2,000μ. To the diagnosis of this species as originally given may be added the description of the cysts and sporocysts, which have recently been secured.

Cysts spherical, average diameter 450μ, the entire surface irregular covered with small elevations and depressions, cyst proper covered with a very thin gelatinous envelope (entirely wanting in some cysts), white when first discharged from the body of the host, but becoming lead gray and finally black as maturation progresses; maturation period for cysts obtained in September, 1913, and kept in water at room temperature, at least ten days; dehiscence simple rupture, with an irregularly spherical central pseudocyst; sporocysts discharged in long chains; each sporocyst subspherical but asymmetrical, one side being distinctly larger and with a greater curvature than the other; when in the chains the sporocysts alternate so that the large side of a sporocyst is always turned away from the large sides of the two adjoining sporocysts; covering of the sporocyst thick, expanded at each end to join with that of the next sporocyst in forming the chains; endosporal mass arranged around a polygonal, hyaline, central spot containing a few granules; sporocysts black or dark brown in color, measuring 7μ x 11μ; sporozoites differentiating in a few days from the endosporal mass, leaving a central hyaline space with numerous granules.

The writer has taken this gregarine from *Eleodes* sp, and *Asida* sp., collected at Denver, Colorado, also from *Asida opaca* Say and *Eusattus* sp. at Boulder, Colorado.

Dactylophoridæ

Epimerite asymmetrical, or asymmetrically placed on the protomerite; cysts dehiscing by simple rupture, usually splitting along the equator, with a pseudocyst; sporocysts cylindrical.

a. Protomerite represented only by a constricted portion of the body; septum wanting..... *Rhopalonia*

aa. Protomerite distinct from the deutomerite; septum present.

b. Deutomerite not divided by septa.

c. Sporocysts cylindrical, usually in chains.

d. Sporont short and ovoid; epimerite asymmetrical, consisting of a conical pointed lateral portion and a marginal row of filamentous processes; the conical portion persisting in the sporont stage.....*Echinomera*

dd. Sporont elongate; epimerite conical, short and lateral; protomerite broad, upturned on one side, that bearing the epimerite; protomerite with digitiform processes.

e. Protomerite bifid on the side away from the epimerite .....*Pterocephalus*

ee. Protomerite not bifid.....*Dactylophorus*

cc. Sporocysts more or less ellipsoidal; not in chains.

f. Sporocysts not pointed; epimerite short, conical and lateral, borne by a much produced portion of the protomerite.....*Trichorhynchus*

ff. Sporocysts pointed.....*Acutispora*

bb. Deutomerite divided by one or more granular septa. ..*Metamera*

Rhopalonia Leger, *1893,* p. 1285.

Type—*R. geophili* Leger, *1893,* p. 1285-1288; from *Geophilus* sp.—*Chilopoda.*

Echinomera Labbe, *1899,* p. 16.

Echinocephalus A. Schneider, *1875,* p. 593. Preoccupied.

Type—*E. hispida* (A. Schneider) = *Echinocephalus hispidus* A. Schneider, *1875,* p. 593, t. 16, f. 36-40; from *Lithobius forticatus* L.—*Chilopoda.*

Echinomera hispida (A. Schneider). Fig. 60.

Echinocephalus hispidus A. Schneider, *1875,* p. 593, t. 16, f. 36-40.

Echinomera hispida, Crawley, *1903a,* p. 52; Wyncote, Pennsylvania, Raleigh, North Carolina, and Cambridge, Mass., from *Lithobius forticatus*: Ellis, *1913a,* p. 465; Boulder, Colorado, from *Lithobius coloradensis* (Cockerell).

Epimerite asymmetrical, consisting of a pointed conical, lateral portion, and a series of more or less filamentous digitiform processes, the whole be-

ing carried by a short base equalling the protomerite in width; the processes of the epimerite disappearing shortly after the animal frees itself from the intestinal wall of the host, but the conical portion of the epimerite persists in the sporont stage giving an asymmetrical margin to the front of the protomerite; sporont ovoid, length of the protomerite from one-seventh to one-eleventh of the length of the deutomerite; cysts spherical, sporocysts cylindrical; average sporonts 80μ x 180μ.

Pterocephalus A. Schneider, *1887*, p. 67.

Nina Grebnicki, *1873*. Preoccupied.

Type—*P. scolopendræ* (Kölliker) = *Gregarina scolopendræ* Kölliker, *1848;* from *Scolopendra* sp.—*Chilopoda.*

Dactylophorus Balbiani, *1889*, p. 41.

Dactylophora Leger, *1892*, p. 124. Preoccupied.

Type—*D. robustus* (Leger), *1892*, p. 124, t. 9; from *Cryptops hortensis* Leach—*Chilopoda.*

Trichorhynchus A. Schneider, *1882*, p. 438.

Type—*T. pulcher* A. Schneider, 1882, p. 438; from *Scutigera* sp.—*Chilopoda.*

Trichorhynchus pulcher A. Schneider. Fig. 61.

Trichorhynchus pulcher A. Schneider, *1882*, p. 438; Crawley, *1903a*, p. 52. *Gregarina megacephala* Leidy, *1889*, p. 11, 1 f.; from *Cermatia forceps.*

Epimerite short and conical, borne by a much produced portion of the protomerite; sporont elongate, reaching the length of 800μ; cysts ovoid; sporocysts cylindrical.

Trichorhynchus lithobii Crawley. Fig. 62.

Trichorhynchus lithobii Crawley, *1903b*, p. 637, pl. XXX, f. 18; Raleigh, North Carolina, from *Lithobius* sp.

Since the determination of this gregarine remains quite uncertain until it is more fully described, a portion of Crawley's original diagnosis is copied here to accompany his figure: "An epimerite was not seen. The protomerite was subcordiform, and displayed in front a differentiation the exact nature of which could not be determined. The deutomerite varied considerably in shape, the animal being quite polymorphic.—The largest individual seen was 195 microns long."

Acutispora Crawley, *1903b*, p. 632.

Type—*A. macrocephala* Crawley, *1903b*, p. 632-633, pl. XXX, f. 1-6; from *Lithobius forficatus* L.—*Chilopoda.*

Acutispora macrocephala Crawley. Figs. 63-64.

Acutispora macrocephala Crawley, *1903b*, p. 632-633, pl. XXX, f. 1-6; Raleigh, North Carolina, from *Lithobius forficatus.*

Epimerite uncertain; sporont rather elongate, tapering posteriorly, the posterior end of the deutomerite broadly rounded; protomerite constricted near its posterior third, narrower than the deutomerite; width of the pro-

tomerite about one-half of its length, which is a little less than one-third of the total length of the animal; sporocysts ellipsoidal, narrow and pointed, about 4μ x 19μ; cysts spherical, with a large lateral pseudocyst.

Metamera Duke, *1910,* p. 261.

Type—*M. schubergi* Duke, *1910,* p. 261-286, pl. 15-16; from *Glossosiphonia complanata* and *Hemiclepsis marginata—Hirudinea.*

This genus at present contains but a single species, *M. schubergi* Duke, known from England and Germany. In his description of this species Duke (*1910,* p. 262), states that it is "identical with a species briefly mentioned by Bolsius in 1895, and the subject of a more detailed but still fragmentary paper in 1896." On the same page Duke calls attention to the fact that Castle (*1900*), "mentions having observed the gregarine seen by Bolsius in about half the specimens of *Clepsine elongata* which he examined." In this roundabout way there exists a North American record of a gregarine probably referable to the genus *Metamera.* This gregarine, listed as *Gregarina complanata* by Castle (*1900,* p. 60) from *Glossiphonia elongata,* is deserving of study when material is obtained.

Stenophoridæ

Dehiscence of cysts by simple rupture; sporocysts ovoid, not in chains; epimerite present only in the intracellular stage; anterior portion of the protomerite with a thin central area in the epicyte so that the protomerite when seen in optical section appears to have a central canal in its anterior end.

Stenophora Labbe, *1899,* p. 15.

Stenocephalus A. Schneider, 1875, p. 584. Preoccupied.

Type—*S. juli* (Frantzius) = *Gregarina juli* Frantzius, *1848,* p. 191-194; from *Julus* sp.—*Diplopoda.*

Cnemidospora A. Schneider, *1882,* p. 446.

The species of this genus are parasites of Diplopods, although two species, *S. erratica* Crawley and *S. gimbeli* Ellis, have been recorded from insects. These two species, as suggested by Crawley (*1907*) regarding his species *S. erratica,* may be accidental and atypical forms of some of the regular Diplopod-infesting *Stenophoræ,* resulting from the introduction of the sporocysts into the wrong host.

Stenophora robusta Ellis. Fig. 72.

Stenophora robusta Ellis, *1912b,* p. 8-11, f.1 a-b; from *Parajulus venustus* Wood and *Orthomorpha gracilis* (Koch), Boulder, Colorado.

Short and ovoid, posterior margin of the deutomerite broadly rounded; protomerite narrower than the deutomerite, subconic, its length about one-eighth of the total length; size under 250μ. The writer has taken this gregarine from specimens of *Orthomorpha* sp., collected at Gold Hill, Colorado, at an altitude of 8400 feet, in November, 1912, by Miss Rosamond Patton.

Stenophora gimbeli Ellis. Fig. 71.

Stenophora gimbeli Ellis, *1913a*, p. 464, f. 3-4; Vincennes, Indiana, from *Harpalus pennsylvanicus* Dej.

Short and ovoid, posterior margin of the deutomerite broadly rounded; protomerite almost as wide as deutomerite, hemispherical, wider than long, its length about one-sixth of the total length; average specimens, 500μ.

Stenophora erratica Crawley. Fig. 69.

Stenophora erratica Crawley, *1907*, p. 221, pl. XVIII, f. 5; from *Gryllus abbreviatus*.

Slightly elongate, posterior margin of the deutomerite broadly rounded; protomerite equalling the deutomerite in width, subconical, its length about one-fourth of the total length; reaching the length of 500μ.

Stenophora julipusilli (Leidy). Fig. 65.

Gregarina julipusilli Leidy, *1853*, p. 238, pl. 10, f. 21-22; from *Julus pusillus*.

Stenophora julipusilli, Crawley, *1903b*, p. 634, pl. XXX, f. 16-17; from *Julus sp.* and *Parajulus* sp.: Hall, *1907*, p. 149; Lincoln, Nebraska.

Somewhat elongate, (young specimens ovoid), posterior margin of the deutomerite rounded; protomerite conical to almost biconic, anterior end rather distinctly pointed; length of the protomerite in adult specimens about one-tenth of the total length.

Stenophora larvata (Leidy). Fig. 70.

Gregarina larvata (Leidy) *1849*, p. 232; from *Julus marginatus*.

Gregarina julimarginati Leidy, *1853*, p. 237, pl. 10, f. 1-20; from *Julus marginatus*.

Stenophora juli, Crawley, *1903a*, p. 51; from *Julus* sp. and *Parajulus* sp.

Elongate, posterior margin of the deutomerite narrowly rounded to almost pointed; protomerite hardly as wide as the widest portion of the deutomerite, hemispherical to subglobose; length of the protomerite about one-twentieth of the total length of adult specimens.

Stenophora spiroboli Crawley. Fig. 66.

Stenophora spiroboli Crawley, *1903a*, p. 51-52, pl. II, f. 22; Raleigh, North Carolina, from *Spirobolus* sp.

Cnemidospora spiroboli Crawley, *1903b*, p. 638-639, pl. XXX, f. 7-9.

Elongate, rather pointed posteriorly, protomerite narrower than the deutomerite; length of the protomerite about one-thirty-second of the total length; cysts spherical; sporocysts spindle-shaped, with heavy epispore, size 12.5μ x 7.5μ. This species may be a synonym of *S. larvata* (Leidy).

Stenophora cockerellæ Ellis. Fig. 67.

Stenophora cockerellæ Ellis, *1912c*, p. 681-685, f. 1-3; Quirigua, Guatemala, from *Parajulus* sp.

Elongate, posterior margin of the deutomerite broadly rounded to almost square; protomerite subglobose with a distinct papilla at its anterior end; width of the protomerite about one half that of the deutomerite, length of the protomerite about one-sixteenth of the total length.

Stenophora elongata Ellis. Fig. 68.

Stenophora elongata Ellis, *1912c,* p. 685-686, f. 4; Quirigua, Guatemala, from *Orthomorpha coarctata* (Saussure).

Extremely elongate, posterior margin of the deutomerite rounded; protomerite as wide or slightly wider than the deutomerite, pentagonal in outline, pointed anteriorly; length of the protomerite about one-twenty-fourth of the total length .

Doliocystidæ

Septum wanting, protomerite continuous with the deutomerite; epimerite simple and digitiform; sporocysts oval with an enlargement at anterior ends; habitat, intestine of marine annelids.

Doliocystis Leger, *1893,* p. 204-206.

Type—*D. pellucida* (Kölliker) = *Gregarina pellucida* Kölliker, *1848,* p. 35, t. 3, f. 31, from *Nereis* sp.—*Polychæta.*

Doliocystis rhynchoboli Crawley.

Doliocystis rhynchobli Crawley, *1903a,* p. 56; *nomen nullum,* Porter, *1897b,* p. 8, pl. 3, f. 37; from *Rhynchobolus americanus* Verrill.

Host List

Host	Gregarine
ANNELIDA	
Rhyncobolus americanus Verrill	*Doliocystis rhyncobli* Crawley
HIRUDINEA	
Glossiphonia nepheloidea (Graf)	
Glossiphonia elongata Castle	*Metamera* sp. ?
DIPLOPODA	
Fontaria sp.	*Amphoroides fontariæ* Crawley
Julus sp.	*Stenophora julipusilli* (Leidy)
Julus minutus Brandt	
Julus pusillus	*Stenophora julipusilli* (Leidy)
Lysiopetalum lacterium (Say)	*Gregarina calverti* Crawley
	Stenophora julipusilli (Leidy)
Orthomorpha coarctata (Saussure)	*Stenophora elongata* Ellis
Orthomorpha gracilis (Knoch)	*Stenophora robusta* Ellis
Orthomorpha sp.	*Stenophora robusta* Ellis
Parajulus venustus Wood	*Stenophora robusta* Ellis
Parajulus sp.	*Stenophora cockerellæ* Ellis
Parajulus sp.	*Stenophora julipusilli* (Leidy)
Polydesmus virginiensis	*Amphoroides polydesmivirginiensis* (Leidy)
Polydesmus sp.	*Amphoroides fontariæ* Crawley
Spirobolus marginatus (Say)	
Julus marginatus Say	*Stenophora larvata* (Leidy)
Spirobolus sp.	*Stenophora larvata* (Leidy)

CHILOPODA

Lithobius coloradensis (Cockerell) ... *Echinomera hispida* (A. Schneider)
Lithobius forficatus (Linn.) ... *Acutispora macrocephala* Crawley
Actinocephalus dujardini A. Schneider
Echinomera hispida (A. Schneider)
Lithobius sp. ... *Trichorhynchus lithobii* Crawley
Scolopendra heros Girard ... *Amphorocephalus amphorellus* Ellis
Scolopendra woodi Meinert ... *Amphorocephalus actinotus* (Leidy)
Scolopocryptops sexspinosus (Say) ... *Amphorocephalus actinotus* (Leidy)
Scolopocryptops sp. ... *Amphorocephalus actinotus* (Leidy)
Scutigera forceps (Rafinesque) ... *Trichorhynchus pulcher* A. Schneider
Cermatia forceps ... *Trichorhynchus pulcher* A. Schneider

ORTHOPTERA

Blaptica dubia (Serv.)
Blabera claraziana Saussure ... *Gregarina blaberæ* Frenzel
Blatta orientalis Linn. ... *Gregarina blattarum* Siebold
Periplaneta orientalis ... *Gregarina blattarum* Siebold
Blattella germanica (Linn.)
Ectobia germanica ... *Gregarina blattarum* Siebold
Brachystola magna Girard ... *Gregarina rigida* (Hall)
Ceuthopilus latens Scudder ... *Gregarina longiducta* Ellis
Ceuthophilus maculatus (Harris) *Gregarina longiducta* Ellis
Ceuthophilus valgus Scudder ... *Gregarina consobrina* Ellis
Chortophaga viridifasciata (De Geer)
Chimarocephalus viridifasciata .. *Actinocephalus pachydermus* (Crawl.)
Dissosteira carolina (Linn.) ... *Actinocephalus pachydermus* (Crawl.)
Locusta carolina Linn. ... *Gregarina locustæcarolinæ* Leidy
Gryllus abbreviatus Serv. ... *Stenophora erratica* Crawley
Acheta abbreviata ... *Gregarina achetæ-abbreviatæ* Leidy
Gigaductus kingi (Crawley)
Gryllus americanus Blatchley ... *Gregarina achetæ-abbreviatæ* Leidy
Ischnoptera pennsylvanica (De Geer) ... *Gregarina blattarum* Siebold
Melanoplus angustipennis (Dodge) *Gregarina rigida* (Hall)
Melanoplus atlanis (Riley) ... *Gregarina rigida* (Hall)
Melanoplus bivittatus (Say) ... *Gregarina rigida* (Hall)
Melanoplus coloradus Caudell
Melanoplus coloradensis ... *Gregarina rigida* (Hall)
Melanoplus differentialis (Uhler) . *Gregarina rigida* (Hall)
Melanoplus femoratus (Burmeister) ... *Gregarina rigida* (Hall)
Melanoplus femur-rubrum (DeGeer) ... *Gregarina rigida* (Hall)

Melanoplus luridus (Dodge) ..... *Gregarina rigida* (Hall)
Panchlora exoleta Burmeister .... *Gregarina panchloræ* Frenzel
Periplaneta americana (Linn.).... *Gregarina blattarum* Siebold
Gregarina serpentula Magalhæs

ISOPTERA

Termes flavipes Kollar ..... *Gregarina termitis* Leidy
Termes lucifugus Rossi ..... *Gregarina termitis* Leidy

ODONATA

Aeshna constricta Say, nymph.... *Geniorhynchus æshnæ* Crawley
Aeshna sp., nymph ..... *Actinocephalus brachydactylus* Ellis

COLEOPTERA

Acilius sp.
Acilius sulcatus (European).... *Bothriopsis histrio* A. Schneider
Alobates pennsylvanicus (DeGeer) *Actinocephalus zophus* (Ellis)
Nyctobates pennsylvanicus ..... *Anthorhynchus philicus* (Leidy)
Nyctobates pennsylvanicus barbata (Knoch) ..... *Actinocephalus zophus* (Ellis)
Asida opaca Say ..... *Stylocephalus giganteus* Ellis
Boletophagus sp.
Boletophagus cornutus ..... *Anthorhynchus boletophagi* (Crawl.)
Colymbetes sp. .....
Colymbetes fuscus Linn. (European) ..... *Bothriopsis histrio* A. Schneider
Cratoparis lunatus (Fab.)..... *Anthorhynchus cratoparis* (Crawl.)
Cucujid larvæ ..... *Gregarina elateræ* Crawley
Dermestes peruvianus Castelnau.. *Pyxinia crystalligera* Frenzel
Dermestes vulpinus Fab. ..... *Pyxinia crystalligera* Frenzel
Dicælus ovalis LeConte ..... *Actinocephalus discæli* (Crawl.)
Elater sp., larvæ ..... *Gregarina elateræ* Crawley
Eleodes hispilabris (Say) ..... *Stylocephalus giganteus* Ellis
Eleodes sp. ..... *Stylocephalus giganteus* Ellis
Eusattus sp. ..... *Stylocephalus giganteus* Ellis
Galerita bicolor Drury..... *Actinocephalus americanus* Crawl.
Harpalus caliginosus Fab. ..... *Gigaductus parvus* Crawley
Actinocephalus harpali (Crawl.)
Harpalus pennsylvanicus DeGeer.. *Gigaductus parvus* Crawley
Stenophora gimbeli Ellis
Holocephala bicornis Olivier..... *Gregarina microcephala* Leidy
Hydaticus sp.
Hydaticus cinereus, larvæ (European) ..... *Bothriopsis histrio* A. Schneider
Hydrophilus sp..... *Legeria terpsichorella* Ellis
Leptochirus edax Sharp..... *Actinocephalus crassus* (Ellis)
Stylocystis ensiferus (Ellis)

Ligyrus relictus (Say)
Scarabeus relictus, larvæ.....*Gregarina scarabeirelecti* Leidy
Lucanus dama Thunb.....*Euspora lucani* Crawley
Necrobia ruficollis Fab.
Corynetes ruficollis .....*Gregarina bergi* Frenzel
Neleus interstitialis Esch.....*Gregarina guatemalensis* Ellis
Passalus cornutus Fab.....*Gregarina passalicornuti* Leidy
Serica brunnea Linn.
Melalontha brunnea .....*Gregarina melalonthæ-brunneæ* (Leidy)
Statira unicolor Blanchard.....*Gregarina statiræ* Frenzel
Tenebrio castaneus Knoch.....*Gregarina grisea* Ellis
Xylopinus saperdioides (Olivier).*Gregarina xylopini* Crawley
Actinocephalus zophus (Ellis)

TUNICATA
Perophora annectens Ritter.....*Gregarina* sp.

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EXPLANATION OF FIGURES

PLATE XVII

FIGURE

1. *Euspora lucani* Crawley. Association. (After Crawley, 1903a, pl. III, f. 38).
2. *Gregarina blaberæ* Frenzel. Sporont. (After Frenzel, 1892, f. 22).
3. *Gregarina serpentula* Magalhæs. Association. (After Magalhæs, 1900, f. 4).
4. *Gregarina calverti* Crawley. Sporont. (After Crawley, 1903a, pl. II, f. 19).
5. *Gregarina achetæ-abbreviatæ* Leidy. Association. Douglas Lake, Michigan.
6. *Gregarina termitis* Leidy. Sporont. Boulder, Colorado.
7. *Gigaductus kingi* (Crawley). Association. (After Crawley, 1907, f. 10).
8. *Gigaductus parvus* Crawley. Association. Vincennes, Indiana.
9. *Gregarina panchloræ* Frenzel. Anterior portion of satellite. (After Frenzel, 1892, f. 20).
10. *Gregarina elateræ* Crawley. Cephalont. (After Crawley, 1903a, pl. I, f. 11).
11. *Gregarina elateræ* Crawley. Sporont. (After Crawley, 1903a, pl. I, f. 5).
12. *Gregarina passalicornuti* Leidy. Association. (After Leidy, 1853, pl. 11, f. 30).
13. *Gregarina rigida* (Hall). Sporont. Boulder, Colorado.
14. *Gregarina statiræ* Frenzel. Association. (After Frenzel, 1892, f. 1).
15. *Gregarina guatemalensis* Ellis. Association. Quirigua, Guatemala.
16. *Gregarina passalicornuti* Leidy. Sporont. New Orleans, Louisiana.
17. *Gregarina xylopini* Crawley. Association. (After Crawley, 1903a, pl. III, f. 30).
18. *Gregarina grisea* Ellis. Association. New Orleans, Louisiana.
19. *Gregarina locustæcarolinæ* Leidy. Cephalont. (After Crawley, 1907, f. 13).

PLATE XVIII

20. *Gregarina blattarum* Siebold. Association. Douglas Lake, Michigan.
21. *Gregarina blattarum* Siebold. Sporocyst. Douglas Lake, Michigan.
22. *Gregarina blattarum* Siebold. Cyst with developing sporoduct-buds. Michigan.
23. *Gregarina consobrina* Ellis. Cephalont. Boulder, Colorado.
24. *Gregarina consobrina* Ellis. Association. Boulder, Colorado.
25. *Gregarina consobrina* Ellis. Dehiscing cyst. Boulder, Colorado.

26. *Gregarina longiducta* Ellis. Dehiscing cyst. Douglas Lake, Michigan.
27. *Gregarina longiducta* Ellis. Cephalont. Douglas Lake, Michigan.
28. *Gregarina longiducta* Ellis. Sporocyst. Douglas Lake, Michigan.
29. *Gregarina longiducta* Ellis. Association. Douglas Lake, Michigan.
30. *Legeria terpsichorella* Ellis. Sporont. Douglas Lake, Michigan.
31. *Actinocephalus brachydactylus* Ellis. Anterior portion of cephalont. Michigan.
32. *Actinocephalus brachydactylus* Ellis. Cephalont. Douglas Lake, Michigan.
33. *Actinocephalus brachydactylus* Ellis. Sporont. Douglas Lake, Michigan.

Plate XIX

34. *Stylocystis ensiferus* (Ellis). Cephalont. Quirigua, Guatemala.
35. *Stylocystis ensiferus* (Ellis). Sporont. Quirigua, Guatemala.
36. *Amphoroides polydesmivirginiensis* (Leidy). Sporont. (After Crawley, 1903a, f. 25).
37. *Amphoroides fontariæ* Crawley. Sporont. East Falls Church, Virginia.
38. *Gregarina bergi* Frenzel. Cephalont. (After Frenzel, 1892, f. 16).
39. *Gregarina bergi* Frenzel. Sporont. (After Frenzel, 1892, f. 17).
40. *Actinocephalus crassus* (Ellis). Sporont. Quirigua, Guatemala.
41. *Geniorhynchus æshnæ* Crawley. Cephalont. (After Crawley, 1907, f. 4).
42. *Bothriopsis histrio* A. Schneider. Cephalont. (After Leger, 1892, pl. XIII, f. 1).
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44. *Pyxinia crystalligera* Frenzel. Sporont. (After Frenzel, 1892, f. 39).
45. *Actinocephalus dujardini* A. Schneider. Cephalont. (After Schneider, 1875, pl. XVI, f. 9.)
46. *Actinocephalus harpali* (Crawley). Sporont. (After Crawley, 1903a, pl. I, f. 1).
47. *Anthorhynchus cratoparis* (Crawley). Cephalont. (After Crawley, 1903a, pl. II, f. 23).
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51. *Amphorocephalus amphorellus* Ellis. Sporont. Boulder, Colorado.
52. *Amphorocephalus amphorellus* Ellis. Cephalont. Boulder, Colorado.
53. *Amphorocephalus actinotus* (Leidy). Cephalont. (After Crawley, 1903a, pl. III, f. 37).
54. *Actinocephalus pachydermus* (Crawley). Sporont. (After Crawley, 1907, f. 3).

55. *Actinocephalus pachydermus* (Crawley). Cephalont. (After Leidy, 1853, pl. II, f. 37).
56. *Actinocephalus americanus* Crawley. Sporont. (After Crawley, 1903b, f. 22).
57. *Anthorhynchus bolctophagi* (Crawley). Sporont. (After Crawley, 1903a, pl. II, f. 26).

Plate XX

58. *Stylocephalus giganteus* Ellis. Anterior portion of a cephalont. Boulder, Colo.
59. *Stylocephalus giganteus* Ellis. Sporont. Boulder, Colorado.
59s. *Stylocephalus giganteus* Ellis. Sporocysts. Boulder, Colorado.
60. *Echinomera hispida* (A. Schneider). Cephalont. Boulder, Colorado.
61. *Trichorhynchus pulcher* A. Schneider. Anterior portion of a cephalont. (After Schneider, 1882, f. 4).
62. *Trichorhynchus lithobii* Crawley. Sporont. (After Crawley, 1903b, f. 18).
63. *Acutispora macrocephala* Crawley. Sporont. (After Crawley, 1903b, f. 1).
64. *Acutispora macrocephala* Crawley. Sporocyst. (After Crawley, 1903b, f. 3).
65. *Stenophora julipusilli* (Leidy). Young sporont. After Leidy, 1853, pl. 10, f. 21).
66. *Stenophora spiroboli* Crawley. Sporont. (After Crawley, 1903a, pl. II, f. 22).
67. *Stenophora cockerellæ* Ellis. Sporont. Quirigua, Guatemala.
68. *Stenophora elongata* Ellis. Sporont. Quirigua, Guatemala.
69. *Stenophora erratica* Crawley. Sporont. After Crawley, 1907, f. 5).
70. *Stenophora larvata* (Leidy). Sporont. (After Leidy, 1853, pl. 10, f. 1).
71. *Stenophora gimbeli* Ellis. Sporont. Vincennes, Indiana.
72. *Stenophora robusta* Ellis. Sporont. Boulder, Colorado.

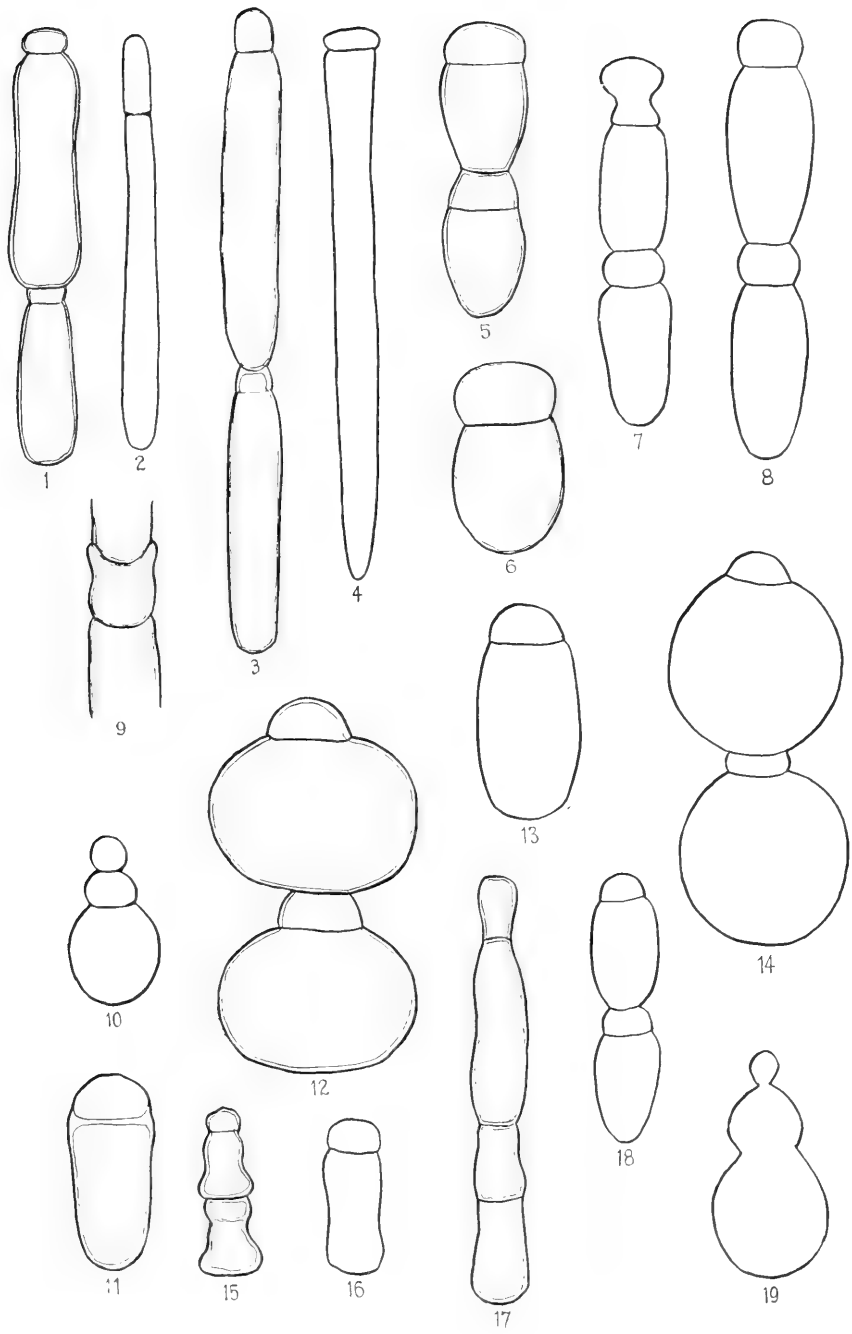

PLATE XVII

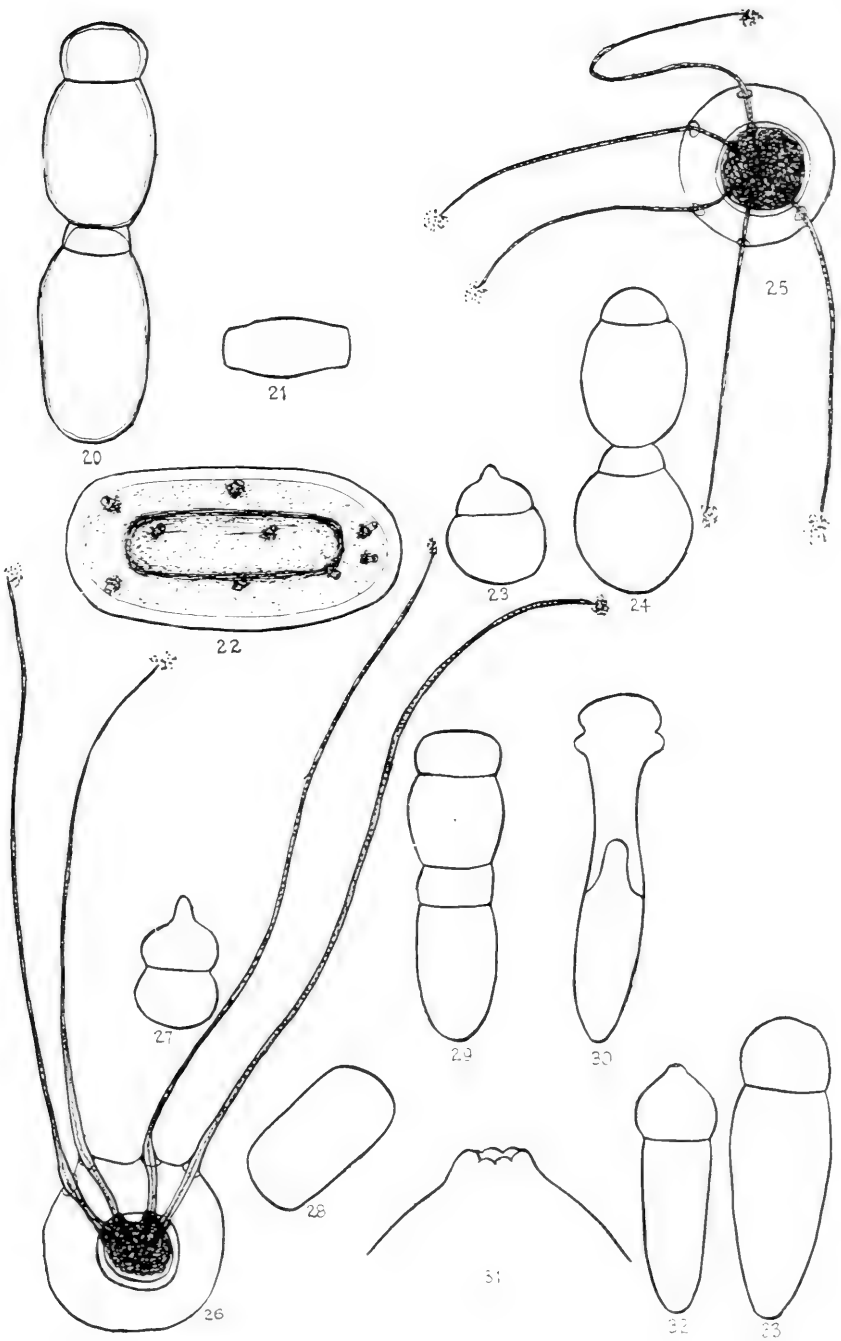

PLATE XVIII

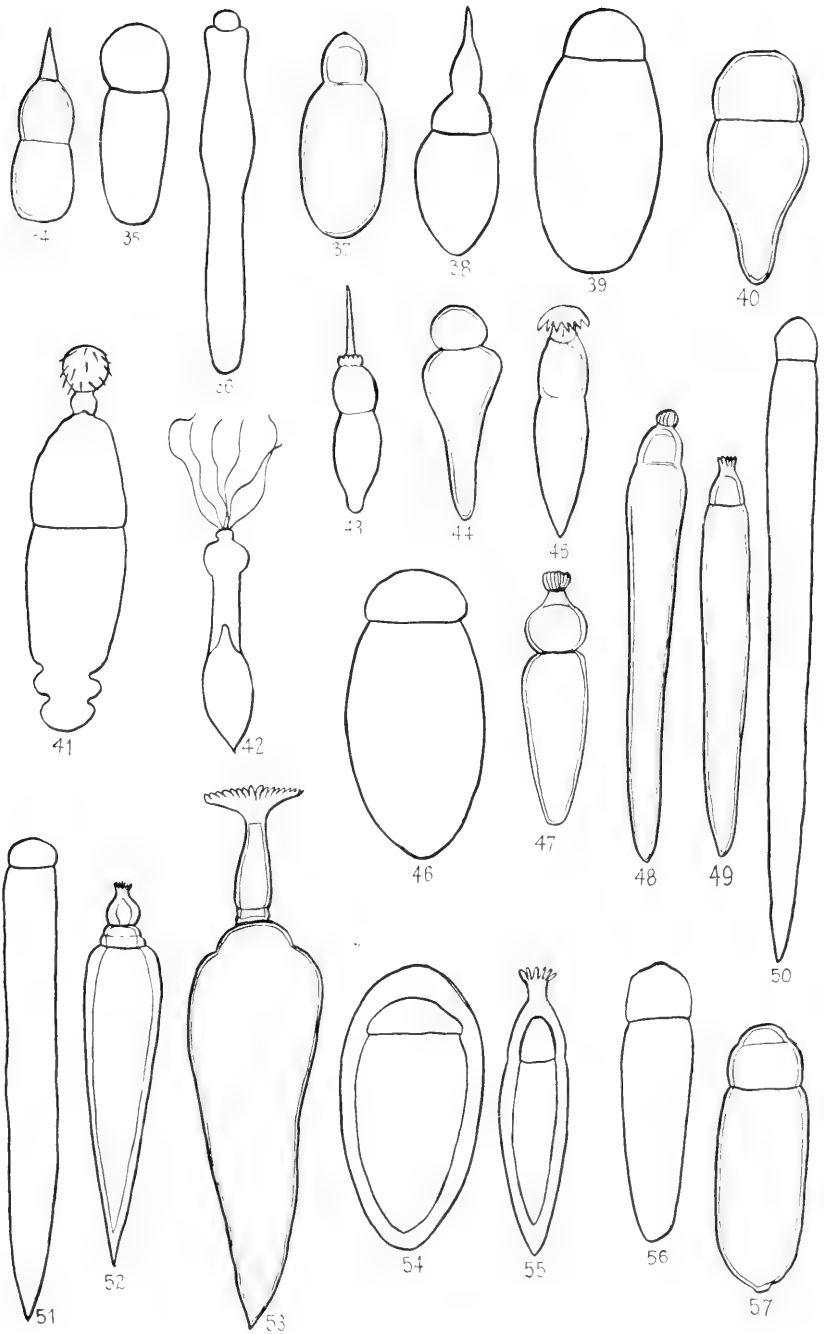

PLATE XIX

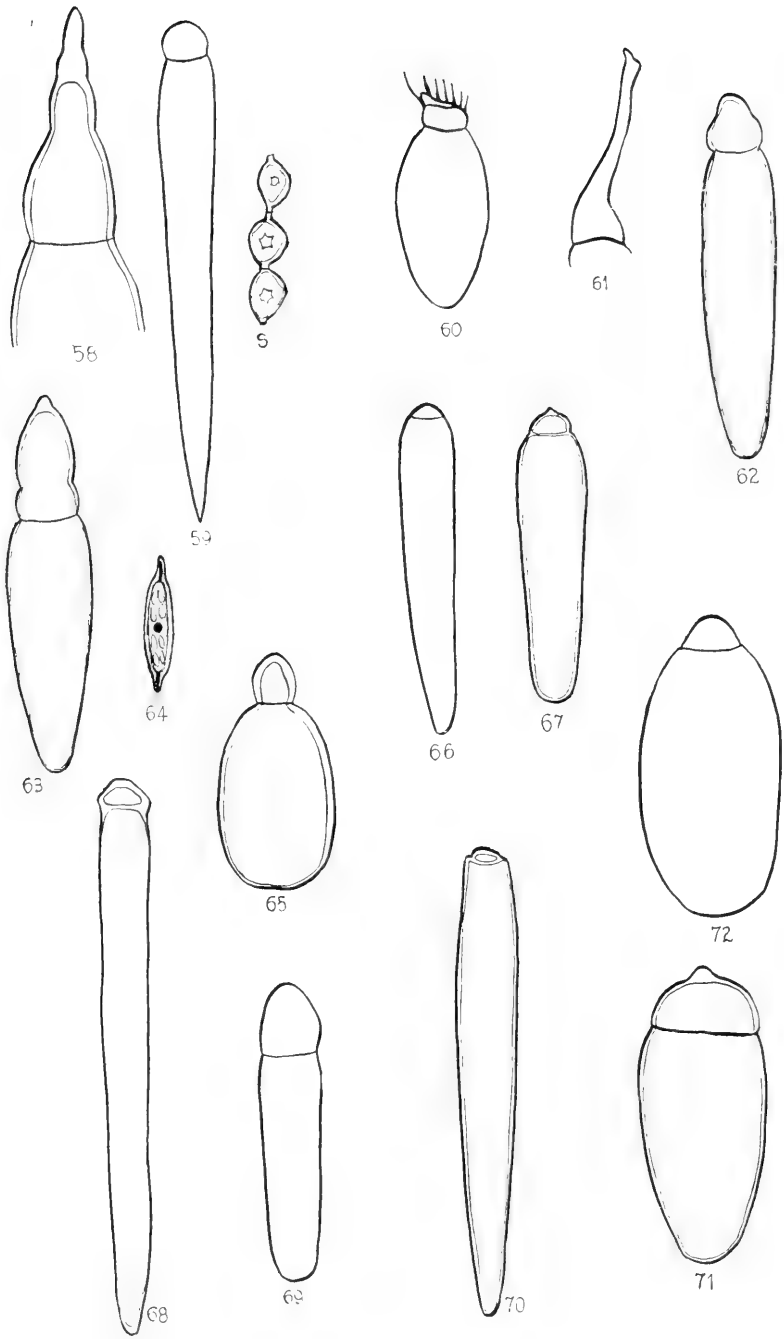

Plate XX

DEPARTMENT OF NOTES, REVIEWS, ETC.

It is the purpose, in this department, to present from time to time brief original notes, both of methods of work and of results, by members of the Society. All members are invited to submit such items. In the absence of these there will be given a few brief abstracts of recent work of more general interest to students and teachers. There will be no attempt to make these abstracts exhaustive. They will illustrate progress without attempting to define it, and will thus give to the teacher current illustrations, and to the isolated student suggestions of suitable fields of investigation.—[Editor.]

A PARAFFIN RIBBON CARRIER

The Carrier described below was designed to handle the paraffin ribbon as it comes from the microtome in such a way as to preserve a perfect series and to eliminate some of the difficulties encountered with the usual method. Not only is the old method of cutting long serial sections into short pieces and laying them upon a sheet of paper tedious but the danger of losing a part of the sections in a sudden draft or of having them hopelessly mixed is great. Without careful shielding, ribbons placed upon paper may not be allowed to lie for any length of time before mounting. With the use of the carrier long unbroken series may be wound on the drum and allowed to remain until used. The writer has allowed a ribbon to remain on the carrier for three days exposed to all the drafts common in the average room and at the end of the time was able to mount a perfect series with no difficulty. The inclined plane shown in the photograph greatly facilitates mounting. The ribbon is unwound from the drum onto the plane where it is cut to the desired lengths. The continuous ribbon does away with the bother of piecing bits together as is frequently necessary when mounting from short strips laid on paper.

Directions for Making

Material.

All the materials necessary for making the machine are easily obtained and at slight expense. The wood used was poplar and yellow pine taken from an old packing box. A one pound coffee tin was made to serve as the cylinder or drum.

Dimensions.

Figure 1. *A.*

1. The Base. 9x6x½ inches. A slot 2½x¼ inches (Fig. 2-10) is cut in the center to accommodate the winged nut (9) which fastens the uprights (3) to the base.

2. The Base to which the uprights are fastened. 7x3x¼ inches. A quarter inch hole is bored in the center of this base to pass the screw of the winged nut through.

3. The Uprights. 9x3x¼ inches. The width narrows four inches from the bottom to 1½ inches. Slots 1x¼ inches are cut in the tops of the uprights (Fig. 1,-D) to accommodate the axles of the drum. The uprights were made particularly for the Leitz Base Sledge microtome and, though the height to which they raise the drum works very well with the rotaries, two inches might be cut from their length with advantage.

4. These are pegs that are inserted four and three quarter inches from the base to carry the inclined plane shown in Fig. 2-11.

5. The Axle Support. This is a disc of wood 2x¼ inches through the center of which a quarter inch walnut axle is thrust. The end of a maple spool is glued to the top of the disc to serve as a bearing (Fig. 1, B-3).

6. The Drum. The lid is soldered onto a one pound coffee tin, the measurements of which are 6x4 inches. The can is covered with blotting paper. This drum will carry about fourteen feet of one-half inch ribbon.

7. The Drum Pulley. 2x¼ inches and grooved as shown in the diagram. The belt runs from this pulley to one made by fastening the ends of a small spool together and which is secured to the inner face of the driving wheel.

8. The Driving Wheel. 3x¼ inches. A handle is inserted in one side as shown in the diagram though very little use is found for it.

9. Winged Nut. ¼ inch in diameter.

Figure 2.

10. Slot 2½x¼ inches in which the bolt of the winged nut

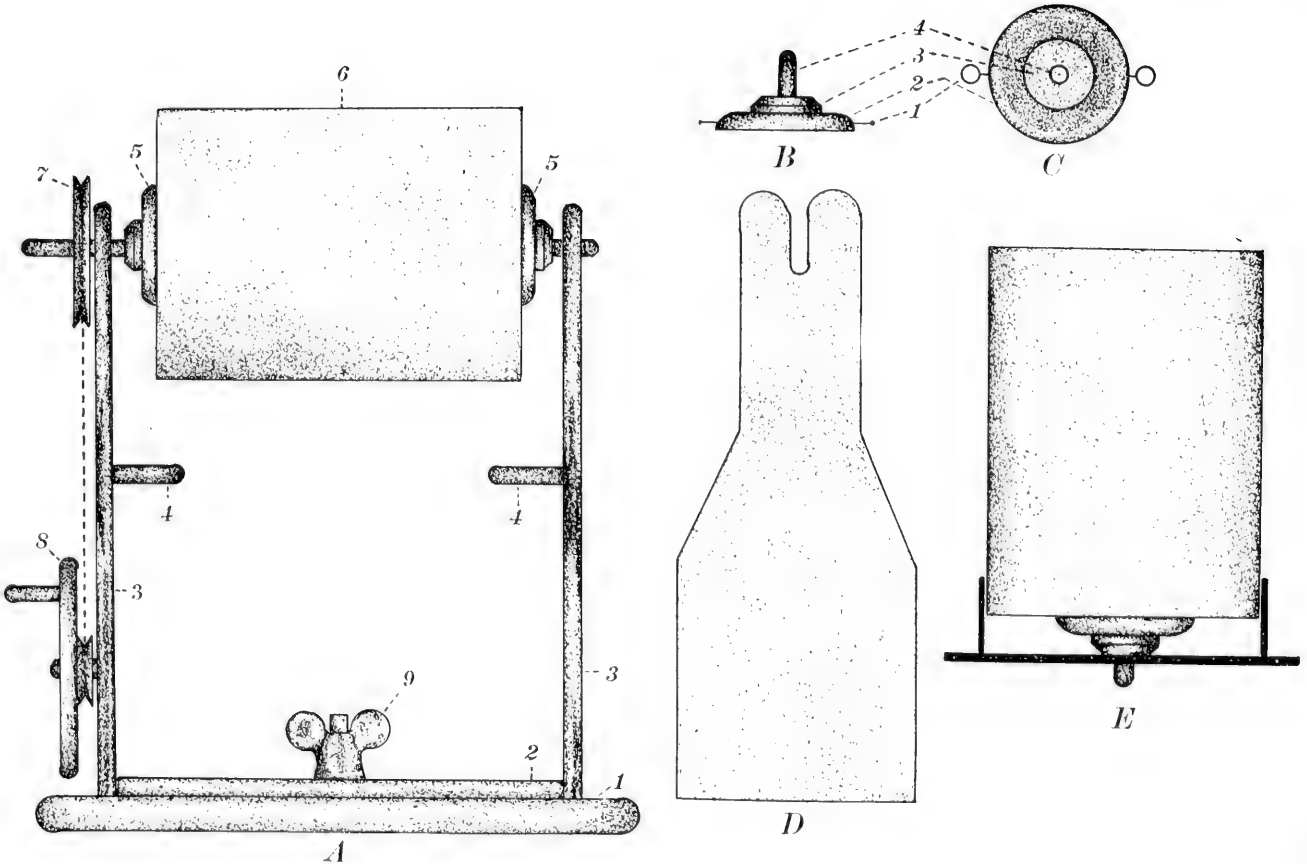

Fig. 1

PLATE XXI

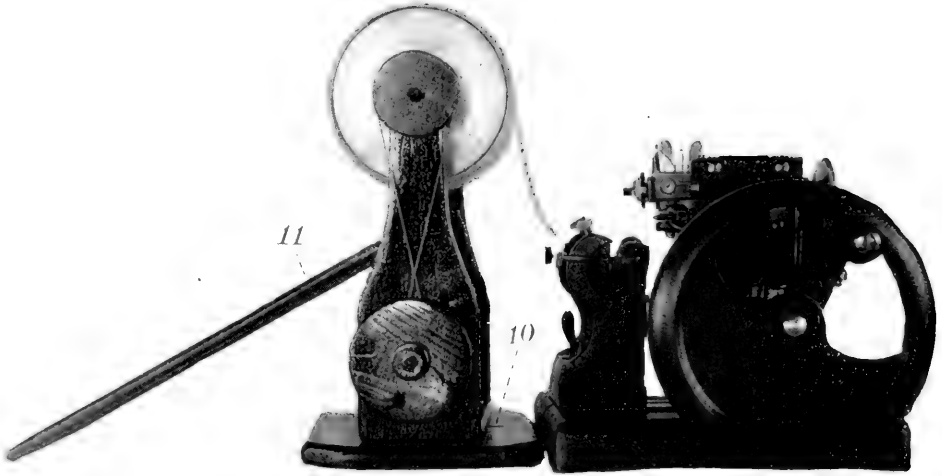

Fig. 2

PLATE XXII

slides. This allows the adjustment of the drum to meet requirements.

11. Inclined Plane. 12x6¾x¼ inches. At one end two pegs are placed to engage those shown in Fig. 1,-A4.

General Directions

The only difficulty that will be encountered in the making of the carrier will be to fasten the axle supports squarely in the center of the drum.

Centering the axles may be easily accomplished by drawing a circle the exact size of the drum on a board and then, after determining the center, drill a hole the size of the axle (¼ inch) through it. Insert the axle into this hole (Fig. 1, E). Drive long brads or nails at the periphery of the circle as shown in this figure so as to hold the drum firmly in place when it is lowered. Coat the axle support with glue and press the drum tightly against it. The nails will hold the drum in place and the axle will be in the exact center of the cylinder.

Glue may serve to fasten the axle permanently to the drum but I find that it does not take a very firm hold of the tin and soon breaks away. This may be overcome by first placing small brads or screw eyes (Fig. 1,-B 1) in the sides of the axle supports and then gluing the discs on as directed above. After the glue has set firmly enough to hold the discs in place solder is run in under the screw eyes and they are thus firmly fastened to the tin.

Directions for Using

Cut a ribbon from eight to ten inches in length and press one end lightly against the blotting paper covering the drum. After this the ribbon is wound on the cylinder as it comes from the microtome (shown in Fig. 2) by thumbing the edge of the driving wheel which revolves the drum very slowly (the drum revolves once to every two and a half revolutions of the driving wheel). The winged nut allows the cyliner to be adjusted to the demands of the particular microtome in use. The ribbon is wound spirally upon the drum by sliding the carrier parallel to the knife. When ready to mount the ribbon is unwound onto the inclined plane which is covered with blotting paper and cut to the desired lengths.

Univ. of Cincinnati. ROBERT THEODORE HANCE.

DIVISION OF LABOR IN THIS DEPARTMENT

It is the hope of the Editor to secure the aid of special workers in the preparation of these notes. Dr. Paul S. Welch has agreed to furnish abstracts of such entomological papers as may seem suitable for the purposes of this department. The following notes are furnished by him. Dr. George R. La Rue will furnish abstracts in histology and microtechnic.

INSECTS AND DISEASE

Doane (Journ. Econ. Ent., 6:366-385, 1913) contributes an important and useful paper entitled: "An Annotated List of the Literature on Insects and Disease for the year 1912." Brief mention is made of the work of Brues and Sheppard, Rosenau, and Anderson and Frost on the transmission of infantile paralysis to monkeys by the common stable fly, *Stomoxys calcitrans*. Whether this is the usual method of transmission among human beings remains to be determined. The *Simuliidæ* have continued to receive attention on account of their possible relation as carriers of pelagra. The work of Forbes, Garman, and Hunter is referred to as presenting very important circumstantial evidence but it remains to be proven that these flies really carry the virus which causes the disease. Other recent work on malaria and mosquitoes, the house fly and typhoid, and trypanosomes and sleeping sickness is briefly mentioned. The chief value of the article lies in the extensive bibliography which contains nearly three hundred references to works on medical entomology issued during 1912.

ADAPTATION IN THE GALL MIDGES

Felt (Canadian Entomol., 45:371-379, 1913) discusses "Adaptation in the Gall Midges." Forms of adaptation are grouped under three heads: (1) Strength, aggressive and defensive, (2) Prolificacy, and (3) Evasive adaptations. Bud galls, leaf galls, stem galls, and root galls are discussed with reference to these classes. In spite of the fact that this group of insects, because of its general similarity in habit, might be thought to exhibit slight variations in structure a number of interesting significant structural modifications are found in the antennæ, palpi, wings, and generative organs. It is shown that the gall midges can not be counted as particularly strong or prolific forms but they have been able to maintain them-

selves largely by evasive adaptations which secure protection for them at the expense of the host plant. This group of insects presents many interesting biological and morphological problems which are unsolved and according to Dr. Felt there is perhaps no insect family better suited in many ways for the study of adaptation.

BIOLOGY OF MAY-FLIES

Morgan (Ann. Ent. Soc. Amer., 6:371-413, 1913) in an article entitled "A Contribution to the Biology of May-flies" gives interesting and valuable data on the different stages of the life history and modifications of the structures of the nymph and adult. The amount of detail makes a short summary impossible. Aside from the considerable amount of new data which is presented, the feature of the paper which is of particular value to teachers and investigators is the complete bibliography on May-flies at the end of the paper which contains approximately 300 titles of foreign and American literature.

HIBERNATION OF THE HOUSE-FLY

Skinner (Ent. News, 24:303-304, 1913) in discussing the often repeated question as to what becomes of the common house-fly during the winter opposes the views held by Howard and Hewitt who claim that the fly hibernates as an adult. His observations lead him to believe that the house-fly hibernates as a pupa and not as an adult.

A PARASITE OF THE CHINCH BUG

McColloch (Can. Ent., 45:342-343, 1913) gives a preliminary report of the discovery of a hymenopterous parasite on the eggs of the chinch bug which promises to be of considerable economic interest. Mr. A. B. Gehen, Entomological Assistant of the Bureau of Entomology, U. S. Dept. of Agric., to whom the adult parasite was sent for identification, determined it as a member of the family *Proctotrypidæ* and states that preliminary examination indicated that it is both a new species and a new genus. The parasite was found in every wheat and corn field examined around Manhattan, Kansas. The average percentage of parasitism has been found to be about 20.8. The length of the life cycle was found to vary from 10 to 18 days and as many as six generations were noted between May 19 and August 10. A complete account is to appear later.

GRASSHOPPERS

Vestal (Biol. Bull., 25:141-180, 1913) contributes an ecological paper on "Local Distribution of Grasshoppers in Relation to Plant Associations". He finds that the distribution of grasshopper species within the region studied bears evident relation to the plant associations and the extent of the latter marks the areas of the different habitats. Grasshoppers select habitats or associations in which favorable conditions are to be found, irrespective of past history, extensiveness, geographical or successional relationships of the vegetation. Only rarely is there any direct relation between grasshopper species and species composition of the plant associations, as few grasshoppers are selective feeders. The following points are also brought out: Grasshopper species can be arranged according to gradients of environmental factors. Grasshopper succession is incidental to the development of vegetation; the change is not only one of species but one of habits as well. Grasshopper species have in general the geographic range of the types of associations which include the necessary physical and vegetational conditions. Species of least definite local distribution are widespread geographically. Seasonal differences in time of activity of grasshopper species, probably in part due to the antagonistic influence of other animals, is marked. Seasonal and local distribution are interrelated. Species of indefinite local distribution have also least definite time distribution.

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