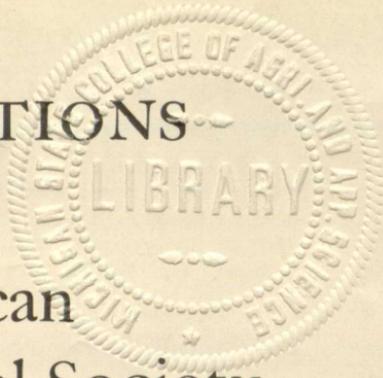


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Vol. XLVIII

OCTOBER, 1929

No. 4

STUDIES OF PARAJULID DIPLOPODS¹
NO. II. THE MICRO-ANATOMY OF THE ALIMENTARY CANAL
OF *PARAJULUS IMPRESSUS* SAY²

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In a series of brief papers it is proposed to present the histology of representative members of the diplopod genus *Parajulus* preliminary to a study of histogenesis in the group. The selection of this genus for the proposed studies was influenced by the following considerations:

- (a) This genus appears to be limited to North America.
- (b) Few studies have been directed toward the members of this particular group.
- (c) The location of eight species in the state of Ohio offers material for comparative studies.
- (d) The extended life history (eleven instars over a period of three years for *P. impressus*) offers an apt occasion for the study of the embryonic origin of adult structures.
- (e) Laboratory culture of the animals for observation of critical periods has proven feasible.
- (f) The chitinous exoskeleton is flexible and can be sectioned, especially just before or after the ecdyses.
- (g) The evidences of primitive arthropod organization in general anatomy give reasons to believe that some trying problems of the relation of the diplopods to other arthropoda and possibly to pro-arthropod stock may be revealed by an extended study.

It is obvious that the studies proposed will involve much technical labor and of necessity extend over a considerable period of time. It is the plan of the writer that other papers follow this study in definite serial order.

¹ The first paper in this series appeared in the *Journal of Morphology and Physiology*, vol. 48, no. 1.

² Published with the aid of a grant from the Spencer-Tolles Fund.

ON THE COMPARATIVE CYTOLOGY OF CERTAIN EUGLE- NOID FLAGELLATES AND THE SYSTEMATIC POSITION OF THE FAMILIES EUGLENIDAE STEIN AND ASTASIIDAE BÜTSCHLI

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There has been a tendency on the part of some protozoologists, Ternetz (1912) for example, to regard *Astasia* as merely a colorless, or non-chlorophyll-bearing stage of *Euglena*, and this belief seems to have influenced Reichenow (1928) in his recent revision of the families of the Euglenida. This author recognizes only two families: (1) Euglenidae, including various genera of the families Euglenidae Stein and Astasiidae Bütschli; and (2) Peranemidae.

During the past few years the writers have noted that in a number of species of *Euglena* the vegetative stages (fig. A, 1) are characterized by a basal bifurcation of the flagellum and by a 'flagellar swelling' near the level of the stigma. Such structural peculiarities of the flagellum have not been seen in any species of *Astasia* or *Menoidium*. These observations have been extended to other genera of the Euglenida in order to determine whether or not such flagellar structures are characteristic of uniflagellate, chlorophyll-bearing euglenoids, and hence whether or not they might serve as taxonomic characters with reference to the families Euglenidae and Astasiidae. On the basis of the observations recorded below, the writers believe that Reichenow is not justified in combining the families Euglenidae Stein and Astasiidae Bütschli into a single 'family Euglenidae.'

Material and methods. The following euglenoids have been examined: (1) Family Euglenidae: *Euglena acus*, *E. agilis*, *E. deses*, *E. gracilis*, *E. granulata*, *E. spirogyra*, *E. terricola*, *E. tripteris*, *Lepocinclis ovum*, *L. ovum* var. *palatina*, *Phacus caudata*, *P. costata*, *P. pleuronectes*, *P. pleuronectes* (?) large variety, *Trachelomonas* sp., *T. abrupta* (?), *T. scabra*, *T. volvocina*; (2) Family Astasiidae: *Astasia dangeardii*, *Menoidium falcatum*, *M. incurvum*.

Material was fixed by the following methods: Schaudinn, Zenkerformic-osmic, Champy, Grassé's (1926a) osmic-chromic-acetic mixture, Mann-Kopsch, Altmann, Bouin and Flemming. The following stains were employed: Bordeaux red followed by iron-hematoxylin, iron-hematoxylin and eosin, Regaud's hematoxylin, and neutral-gentian (after the method of Charipper, 1928). For our purposes, Schaudinn's fixative, followed by Bordeaux red and iron-hematoxylin, has been most useful. The centrifuge method of concentrating material was used in most cases.

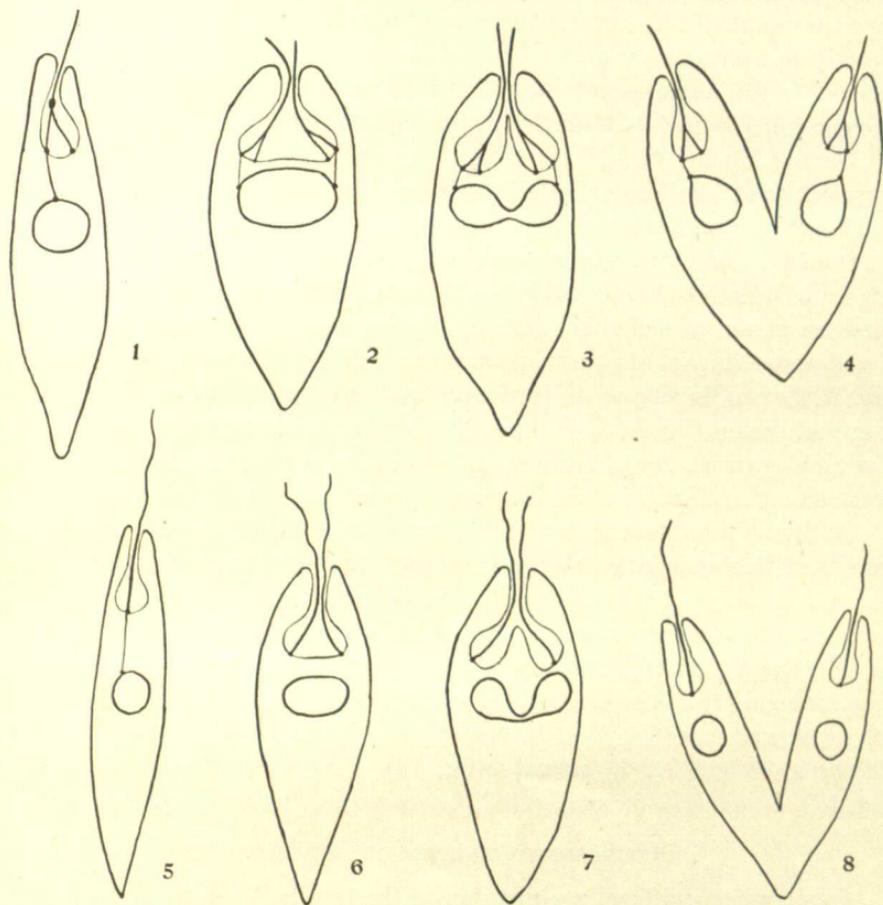


Figure A. Diagrammatic sketches of *Euglena* (1-4) and *Astasia* (5-8). 1. *Euglena*, vegetative stage showing bifurcated flagellum with flagellar swelling, and rhizoplast extending from one of the blepharoplasts to a granule ("extranuclear centrosome") on the nuclear membrane. 2. Late prophase or metaphase, with two bifurcated flagella but no flagellar swellings. 3. Anaphase. 4. Telophase. 5. *Astasia*, vegetative stage showing non-bifurcated flagellum without flagellar swelling, and rhizoplast extending to nuclear membrane. 6. Late prophase. 7. Anaphase. 8. Telophase.

NEUROMOTOR SYSTEM OF EUGLENIDAE

In a typical uniflagellate chlorophyll-bearing euglenoid (fig. A, 1) the flagellum bifurcates near the level of the stigma and the two rami end, each in a blepharoplast, in the posterior wall of the gullet ('reservoir'). At or near the point of bifurcation there is a 'flagellar swelling' which is usually directly opposite the stigma. From one of the blepharoplasts a rhizoplast extends to the nuclear membrane, where it ends in a small granule ('extra-nuclear centrosome' of Hall, 1923; 'parabasal homologue' of Baker, 1926).

During binary fission the flagellar swelling disappears (fig. A, 2-4), apparently at the beginning of flagellar duplication. In some species of *Euglena* (Hall and Jahn, 1929) the stigma also breaks up into its component granules at about this same stage. In other species (Grassé, 1926a, b) the stigma divides into two equal parts. Whether or not there is any correlation between structural changes in the stigma and the disappearance of the flagellar swelling is, of course, purely conjectural. At a late prophase stage (fig. A, 2) two flagella with bifurcated endings are present, and in the later stages of fission (fig. A, 3, 4) the gullet is constricted into two portions, each of which contains one of the flagella. In each daughter organism the flagellar swelling is reformed after the completion of binary fission.

So far as our present investigations have been extended, the different species of *Euglena* show this typical structure of the flagellum: *Euglena acus* (fig. 1), *E. agilis* (fig. 8), *E. deses* (fig. 12), *E. gracilis* (fig. 7), *E. granulata* (fig. 21), *E. spirogyra* (fig. 11), *E. terricola* (fig. 9), and *E. tripteris* (fig. 3).

The same structural features of the flagellum are evident in other uniflagellate genera of the Euglenidae: *Phacus caudata* (fig. 18), *P. costata* (fig. 6.), *P. pleuronectes* (fig. 20), *P. pleuronectes* (?) large variety (fig. 2), *Trachelomas* sp. (fig. 10), *T. abrupta* (fig. 13), *T. scabra* (fig. 4), *T. volvocina* (fig. 17), *Lepocinclis ovum* (fig. 16), *L. ovum* var. *palatina* (fig. 19).

NEUROMOTOR SYSTEM OF ASTASIIDAE

In a typical uniflagellate member of the family Astasiidae the flagellum is non-bifurcated and ends in a single blepharoplast near the posterior end of the gullet (fig. A, 5). In the later prophases of binary fission (fig. A, 6) duplication of the flagellum occurs, and in later stages of fission (fig. A, 7, 8) the original gullet is constricted into two, each containing one flagellum. Thus *Astasia* differs from *Euglena* in that the flagellum shows no bifurcation, no 'flagellar swelling,' and ends in a single blepharoplast instead of two.

This characteristic structure of the flagellum has been observed in *Astasia dangeardii* (pl. 2, fig. 14), *Menoidium falcatum* (pl. 2, fig. 15) and *M. incurvum* (pl. 1, fig. 5). *Euglenopsis vorax* also shows a non-bifurcated flagellum without a 'flagellar swelling' (Hall and Powell, 1927), and a flagellum of similar structure has been reported in several other uniflagellate,

non-chlorophyll-bearing species of Euglenida—*Copromonas subtilis* (Dobell, 1908), *Copromonas major* (Berliner, 1099), *Astasia levis* (Belar, 1916), *Scytomonas pusilla* (Schüssler, 1917), *Jenningsia diatomophaga* (Schaeffer, 1918) and *Peranema trichophorum* (Hall and Powell, 1928).

CONSTANCY IN STRUCTURE OF NEUROMOTOR SYSTEM

It has been shown that a bifurcation of the flagellum is characteristic of the different species of uniflagellate Euglenidae examined and that the flagellum in such species always shows a 'flagellar swelling' at the level of the stigma in vegetative stages. These findings are in accord with the observations of Wager (1899) on *Euglena viridis*, Jollos (1925) on *Trachelomonas reticulata*, Baker (1926) on *Euglena agilis*, Grassé (1926a) on *Euglena proxima*, Ratcliffe (1927) on *Euglena spirogyra*, and Mitchell (1928) on *Euglena caudata* and *E. viridis*.

Such structural features of the flagellum have not, however, been observed in vegetative stages of any of the non-chlorophyll-bearing species examined by us or by other workers (Dobell, Berliner, Belar, Schüssler and Schaeffer, cited above). The statement of Jollos (1927), that uniflagellate euglenoids "besitzt dabei ein doppelte Geisselwurzel, ein Umstead, der wohl auf ihnen zusammenhang mit zweigeisseligen Arten hinweist," is inaccurate in that it is applicable only to the Euglenidae and not to the Astasiidae.

The existence of such structural differences between the Astasiidae and the Euglenidae suggests that these features may serve as taxonomic characters. The extent of their application depends, of course, upon whether or not such structural features of the flagellum are constant for each species. Certain changes do occur in the Euglenidae during binary fission. Ratcliffe (1927) has already shown that the flagellar swelling in *Euglena spirogyra* is resorbed in early division stages, but reappears on the flagellum of each daughter individual. Each of the two flagella found in late prophase and succeeding stages, however, shows the typical bifurcation. These observations have been confirmed in our own preparations of *Euglena agilis*, *E. gracilis* and other Euglenidae. Hence, the structure of the flagellum in the Euglenidae seems to be constant enough to serve as a taxonomic character.

The observations of several workers, however, are not in complete agreement with those of the writers. Haase (1910), for example, has described an unusual type of flagellar insertion in *Euglena sanguinea*, a form which we have not examined. In this species the flagellum bifurcates, as in other Euglenidae, shortly after it enters the gullet, but the two rami instead of ending in the wall of the gullet pass posteriorly into the cytoplasm, where they converge in a single 'basal granule' posterior to the nucleus (fig. B, 1).

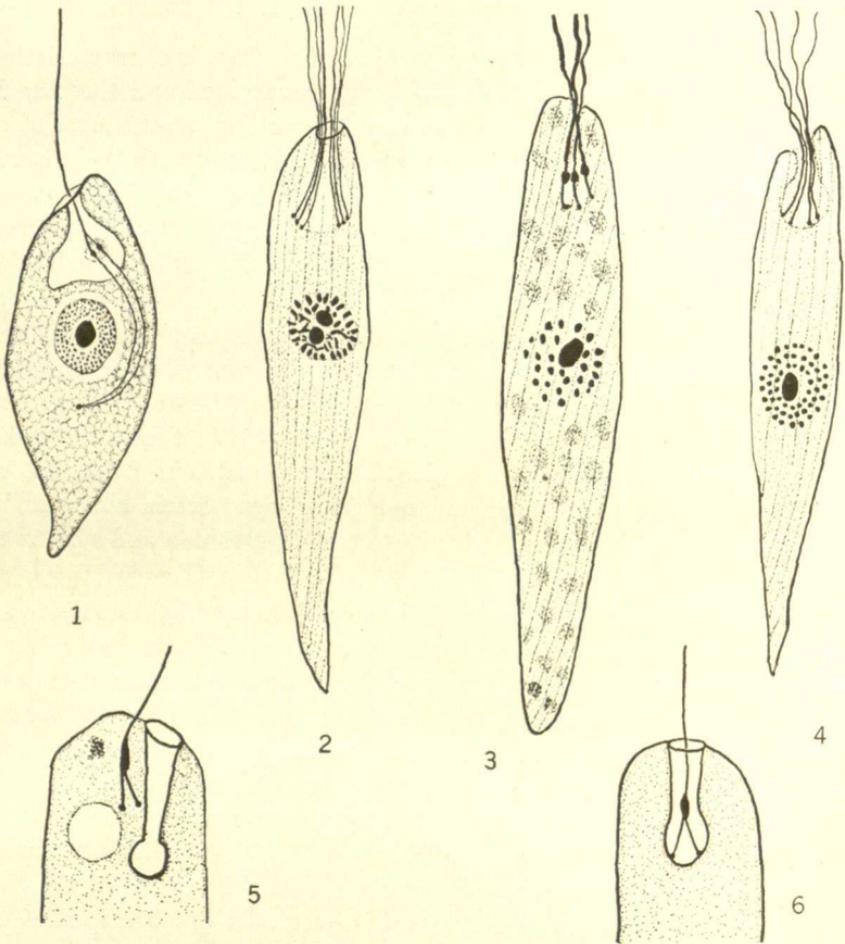


Figure B. 1. *Euglena sanguinea* (after Haase, 1910). 2. *Euglenamorphia hegneri*, variety *pellucida* with six flagella (after Wenrich, 1924). 3. *Euglenamorphia hegneri*, green variety with three flagella (after Wenrich). 4. *Euglenamorphia hegneri*, variety *pellucida* with four flagella (after Wenrich). 5. *Euglena gracilis*, sketch of living material (after Tannreuther, 1923). 6. *Euglena gracilis*, from stained preparations (after Tannreuther).

This condition is so entirely different from the flagellar insertion in other species of *Euglena* that no explanation has occurred to the writers.

Bretschneider (1925), in addition, has figured *Phacus costata* with no bifurcation of the flagellum and without the usual flagellar swelling. In our own preparations of a species believed to be *Phacus costata* a bifurcation of the flagellum and a flagellar swelling are both distinctly evident, and we are unable to account for Bretschneider's failure to observe them.

Tannreuther (1923), in some of his figures of living *Euglena gracilis*, has shown the bifurcated flagellum ending in the cytoplasm outside the gullet (fig. B, 5), while in figures based on stained preparations (fig. B, 6) the flagellum ends in the posterior wall of the gullet as in other species of *Euglena*. In our own preparations of this species the flagellum always ends in the gullet, and it seems probable that Tannreuther misinterpreted what he saw in the living flagellates. There is, furthermore, no reliable evidence from any source that such changes in position of the flagellum occur in any species of the Euglenidae.

In Euglenidae with two or more flagella the flagellar bifurcation is lacking. In *Eutreptia viridis* (Steuer, 1904) there are two, and in *Euglenamorpho hegneri* (Wenrich, 1924) three non-bifurcated flagella which end in the wall of the gullet; in both species, however, each flagellum in vegetative stages shows a flagellar swelling similar to that seen at the bifurcation in uniflagellate Euglenidae.

Within the limits of our present observations on euglenoids and those of certain earlier workers (Steuer, 1904; Berliner, 1909; Belař, 1916; Schüssler, 1917; Hall, 1923; Baker, 1926; Ratcliffe, 1927; Hall and Powell, 1928), the number of flagella shows no change within the species except for the increase in binary fission and the resorption which precedes encystment and development of non-swimming stages. Wenrich (1924), however, in his description of *Euglenamorpho Hegneri* and its colorless variety *pellucida*, has described an increase in number of flagella and other changes which he considers 'evolutionary':

"The differences in shape of body, number of flagella, structure of the nucleus, in surface striae and in reservoir, in addition to the difference in color, would probably justify the formation of a different genus if the intermediate stages had not been discovered. When one realizes that such a transformation does take place it is almost like having seen evolution occur. . . . It is difficult to understand why . . . approximately 40% of the *pellucida* should have four, 40% have six, and the remaining 20% either two, three or five flagella. Six flagella can be accounted for by assuming an abnormal doubling coordinated with hypertrophy . . . of the nucleus. Three flagella would occur as a result of the division of a six-flagellated individual or as a result of recent transformation from the type. . . . transformation may be accompanied by the addition of one flagellum, possibly on account of the hypertrophy of the nucleus, thus giving four. Two flagellated individuals would result from the division of those with four. The occurrence of a five-flagellated individual is a further indication of instability of flagellar conditions and may indicate the addition of two instead of one or three flagella."

Reichenow (1928) even seems inclined to regard Wenrich's green and colorless forms of *Euglenomorpha* as separate species: ". . . zwei Varietäten, die vielleicht verschiedene Arten sind, einer dreigeißeligen mit Chromatophoren und Stigma und einer farblosen mit vier bis sechs Geißeln." As a matter of fact, the points of insertion and the variations in number of flagella in *pellucida* are surprisingly suggestive of behavior of the flagellum in binary fission of euglenoids (Compare figure A with figure B, 2-4). Individuals are found with three, four, five and six flagella, and this fact in itself might indicate that flagellar duplication is taking place. Furthermore, in eleven of Wenrich's figures of *pellucida*, four of which are apparently considered typical vegetative stages, the flagella are inserted in two groups, the blepharoplasts of which lie near opposite sides of an enlarged gullet (fig. B, 2, 4). This type of insertion of the flagella is strikingly similar to that observed in *division stages* of other *Euglenida* (fig. A, 2, 3, 6, 7). Since stained preparations of *pellucida* seem to have been made only "from the rectal contents" (of the tadpole) in which division was "rapid in the host," and since "stages of mitosis in the green variety . . . seem to be accompanied by transformation into the pellucid variety," it would seem that Wenrich has not eliminated the possibility that the apparent increase in number of flagella accompanying the transformation into *pellucida* is merely that which occurs normally in binary fission of euglenoids. Given a mature vegetative stage possessing three flagella, it follows that in the progressive duplication of flagella in binary fission, individuals with three, four, five and six flagella would be expected. In a similar case, binary fission of the biflagellate *Eutreptia viridis* (Steuer, 1904), stages with two, three and four flagella are observed previous to constriction of the gullet. Biflagellate forms of Wenrich's variety *pellucida* might be accounted for by assuming that fission was completed before the end of flagellar duplication.

It has already been pointed out that resorption of the flagellar swelling accompanies binary fission in *Euglena*, just as described by Wenrich in the green variety of *Euglenomorpha hegneri*. Hence, the resorption which normally accompanies fission in *Euglenidae* may account for the absence of the flagellar swellings in the pellucid variety.

Furthermore, Wenrich's figures of division in *pellucida* show no stages earlier than a very late prophase, and in the experience of the writers duplication of the flagella usually begins before that stage in binary fission of euglenoids. Hence, some of Wenrich's supposed vegetative stages of the pellucid variety (fig. B, 2, 4) with four to six flagella might perhaps be considered early prophases instead. This interpretation is suggested also by the structure of the nuclei in some of these supposed vegetative stages; the appearance is more like that of prophase than of interphase nuclei of euglenoids.

Wenrich found also that "in the pellucid variety there is a marked ten-

dency for the nucleus to hypertrophy." Other workers have shown that an appreciable increase in size of the nucleus occurs during prophase stages in the division of various euglenoids. Wenrich observed, in addition, that "the reservoir is regularly of larger size in *pellucida*;" this was interpreted as a "probably abnormal enlargement." In other euglenoids, however, enlargement of the reservoir (gullet) is a normal process which begins in pro-phases of binary fission.

The only valid difference between the two varieties seems to be the absence of chlorophyll in the pellucid variety. Yet it is a well known fact that various species of *Euglena* lose their chlorophyll when grown in the dark in cultures containing abundant organic food material in solution. These two conditions—lack of sunlight and abundance of organic food material—are supplied by the gut of the tadpole, the environment of *Euglenamorphia hegneri*. It seems somewhat probable, therefore, that Wenrich's variety *pellucida* merely represents prophase and later division stages of *Euglenamorphia hegneri* without chlorophyll, and that there is no necessity for establishing a separate variety *pellucida*—at least, with the implication that mutation, or "evolution," has occurred.

STATUS OF THE FAMILIES EUGLENIDAE AND ASTASIIDAE

So far as the present evidence extends it would seem that, aside from changes occurring in binary fission, the flagellum in Euglenidae and Astasiidae is constant in structure, in point of insertion and in number for any given species, and that the two families show certain characteristic differences in structure of the flagellum. These conclusions lead us to question the classification which Reichenow (1928) has proposed for the Euglenida. This author divides the order into two families: (1) Euglenidae, and (2) Peranemidae. The older families Euglenidae Stein and Astasiidae Bütschili have been combined as Reichenow's 'family Euglenidae.' The group is characterized as follows: radially symmetrical forms with or without chromatophores; and it includes the following genera: *Astasia*, *Euglena*, *Eutreptia*, *Colacium*, *Menoidium*, *Phacus* and *Trachelomonas*. The Peranemidae, on the other hand, are said to be bilaterally symmetrical, to possess a mouth opening and to lack chromatophores. As a matter of fact, the flagellates in both groups possess a well defined cytostome ('mouth') and gullet, so that this feature is obviously not limited to the family Peranemidae. Furthermore, the criterion of symmetry, which appears to be the only feature distinguishing between the two groups, is of rather questionable significance. The *Euglenida* are, for the most part neither truly bilateral nor truly radial in symmetry, and there is no established basis for characterizing any particular genus by one type of symmetry or the other. Hence, the common possession of a hypothetical 'radial symmetry' is hardly a valid reason for combining the non-chlorophyll-bearing Astasiidae (*Astasia*

Menoidium, etc.) with the chlorophyll-bearing *Euglena* and its relatives. Aside from the presence of paramylum bodies, a cytostome and gullet, and a nucleus of the euglenoid type—features common to the Peranemidae as well—the various genera of Reichenow's 'family Euglenidae' show no diagnostic characteristic which is common to all of them.

In addition to Reichenow's lack of a logical basis for his 'family Euglenidae,' the writers have shown that there are seemingly sound morphological grounds for separating *Euglena* and related genera from *Astasia* and *Menoidium*. Various species of *Euglena*, *Phacus*, *Trachelomonas* and *Lepocinclis* show a bifurcation of the single flagellum and also a flagellar swelling near the level of the stigma. Such flagellar swellings have also been described in the biflagellate *Eutreptia viridis* (Steuer, 1904) and the triflagellate *Euglenamorphia hegneri* (Wenrich, 1924), although the flagella in these species are not bifurcated. In none of the species of *Astasia* or *Menoidium* examined does the flagellum show either of these peculiarities. This is true also for *Copromonas subtilis* (Dobell, 1908), *Copromonas major* (Berliner, 1909), *Astasia levis* (Belař, 1916) and *Scytomonas pusilla* (Schüssler, 1917).

Furthermore, there is no stigma in *Astasia levis*, *Copromonas*, *Scytomonas*, or in the species of *Astasia* and *Menoidium* examined by the writers. While such an organelle has been described in several species of 'Astasia,' some parasitic and some free-living, it is not impossible that such descriptions have been based upon observations of chlorophyll-free euglenas. Belař (1916), for example, concluded on the basis of cytological characteristics that *Astasia captiva* Beauchamp is merely a colorless form of some species of *Euglena*. Furthermore, the existence of such a form as *Euglena quartana* Moroff, a species with a stigma but no chlorophyll under conditions of saprozoic nutrition, suggests the need for caution in placing such forms in the genus *Astasia*. On the basis of the evidence available the writers would be inclined to transfer the stigma-bearing species—*Astasia captiva* Beauchamp, *Astasia mobilis* Alexeieff (if a stigma is actually present), *Astasia ocellata* Khawkin, *Astasia chaetogastris* Codreanu and Codreanu (1928)—to the genus *Euglena* until it can be shown that the cytological structure of these forms justifies a position in the genus *Astasia*.

Although it seems evident that the Astasiidae should remain recognized as a family separate from the Euglenidae, there are still differences of opinion as to the limits comprised by the family Astasiidae. Calkins (1926), for example, has attempted to establish the Astasiidae as a family of *uniflagellate* forms including the following genera: *Astasia*, *Clautriavia*, *Euglenopsis*, *Jenningsia*, *Menoidium*, *Peranema*, *Petalomonas*, *Scytomonas* and *Urceolus*. The biflagellate forms without chromatophores are placed in the new family Heteronemidae.

The system of Calkins has the possible advantage of simplicity in diagnosis, yet both his families (Astasiidae and Heteronemidae) are heterogen-

eous aggregates of holozoic and saprozoic forms with and without a pharyngeal-rod apparatus (Calkins' "parabasal body"), the members of each family showing only one diagnostic characteristic—the number of flagella. Rhodes (1926) has raised the objection that "this departure seems based upon misinterpretation and is unjustified." From Rhodes' (1926) description of *Heteronema*, Hall and Powell (1927) were led to believe that "Rhodes, in demonstrating that the staborgan of *Heteronema acus* serves as a mouth in the ingestion of food, has shown that there is an even more striking difference between *Peranema* and *Heteronema* than the mere number of flagella. Hence, . . . that Rhodes, instead of weakening the status of Calkins' family Heteronemidae, has really presented some very good evidence that *Peranema* and *Heteronema* should be separated and that the family Heteronemidae should stand" (p. 162).

Recent investigations carried on in our laboratory have shown that, in spite of Rhodes' statements in regard to *Heteronema*, the pharyngeal-rod apparatus is essentially similar in structure and probable function in these two flagellates; and furthermore, that this organelle apparently does not function as a "true cytostome" in ingestion of food, but seems to serve rather as a supporting system for the cytostome and gullet which are characteristic of the euglenoids as a group. This similarity of the pharyngeal organelles in the biflagellate *Heteronema* and the uniflagellate *Heteronema* obviously contradicts the assumption (Hall and Powell, 1927) that the two genera should be placed in separate families. In view of this situation, which involves *Jenningsia* as well as *Peranema* and *Heteronema*, Calkins' system is not entirely satisfactory.

Lemmermann (1913), on the other hand, characterizes the Astasiidae as saprozoic, radially symmetrical forms with one or two flagella. It has already been pointed out that the criterion of symmetry, in the Euglenida, is anything but a satisfactory basis of classification; and furthermore, the lack of adequate knowledge of the feeding habits of some genera would seem to be a handicap in classifying the colorless euglenoids on the basis of method of nutrition. Hence, neither the system of Calkins nor that of Lemmermann is at present entirely free from objection, and for this reason it seems to the writers that an adequate classification of the euglenoids without chromatophores must await further investigation of the cytology and feeding habits of these flagellates.

SUMMARY

It has been shown that, in various species of *Phacus*, *Euglena*, *Trachelomonas* and *Lepocinclis*, vegetative stages are characterized by a basal bifurcation of the flagellum into rami which end in separate blepharoplasts, and by a 'flagellar swelling' at the level of the stigma. Such structural fea-

tures of the flagellum were not observed in non-chlorophyll-bearing euglenoids (Astasiidae). On the basis of such structural differences it is concluded that Reichenow (1928) is not justified in combining the families Euglenidae Stein and Astasiidae Bütschli into a single 'family Euglenidae.'

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PLATE XLVII

- FIG. 1. *Euglena acus*, showing bifurcated flagellum with flagellar swelling, flagellar rhizoplast extending to nucleus, and bacilliform paramylum bodies; S-BR-IH; $\times 750$ ca.
- FIG. 2. *Phacus pleuronectes* (?) large variety, showing bifurcated flagellum with relatively large flagellar swelling, numerous chromatophores; surface striations—approximately parallel to the rows of chromatophores—are not indicated; S-BR-IH; $\times 1000$.
- FIG. 3. *Euglena tripteris*, flagellar structure and chromatophores; S-BR-IH; $\times 2025$.
- FIG. 4. *Trachelomonas scabra*, flagellar structure, two chromatophores; S-BR-IH; $\times 2025$.
- FIG. 5. *Menoidium incurvum*, non-bifurcated flagellum, flagellar rhizoplast extending to nucleus, surface striations indicated; S-Br-IH; $\times 1550$ ca.
- FIG. 6. *Phacus costata*, flagellar structure and chromatophores; surface striations indicated diagrammatically; S-BR-IH; $\times 1570$.
- FIG. 7. *Euglena gracilis*, late prophase stage with two bifurcated flagella; gullet partly constricted; S-BR-IH; $\times 2025$.
- FIG. 8. *Euglena agilis*, flagellar structure, chromatophores with pyrenoids; S-BR-IH; $\times 1750$.

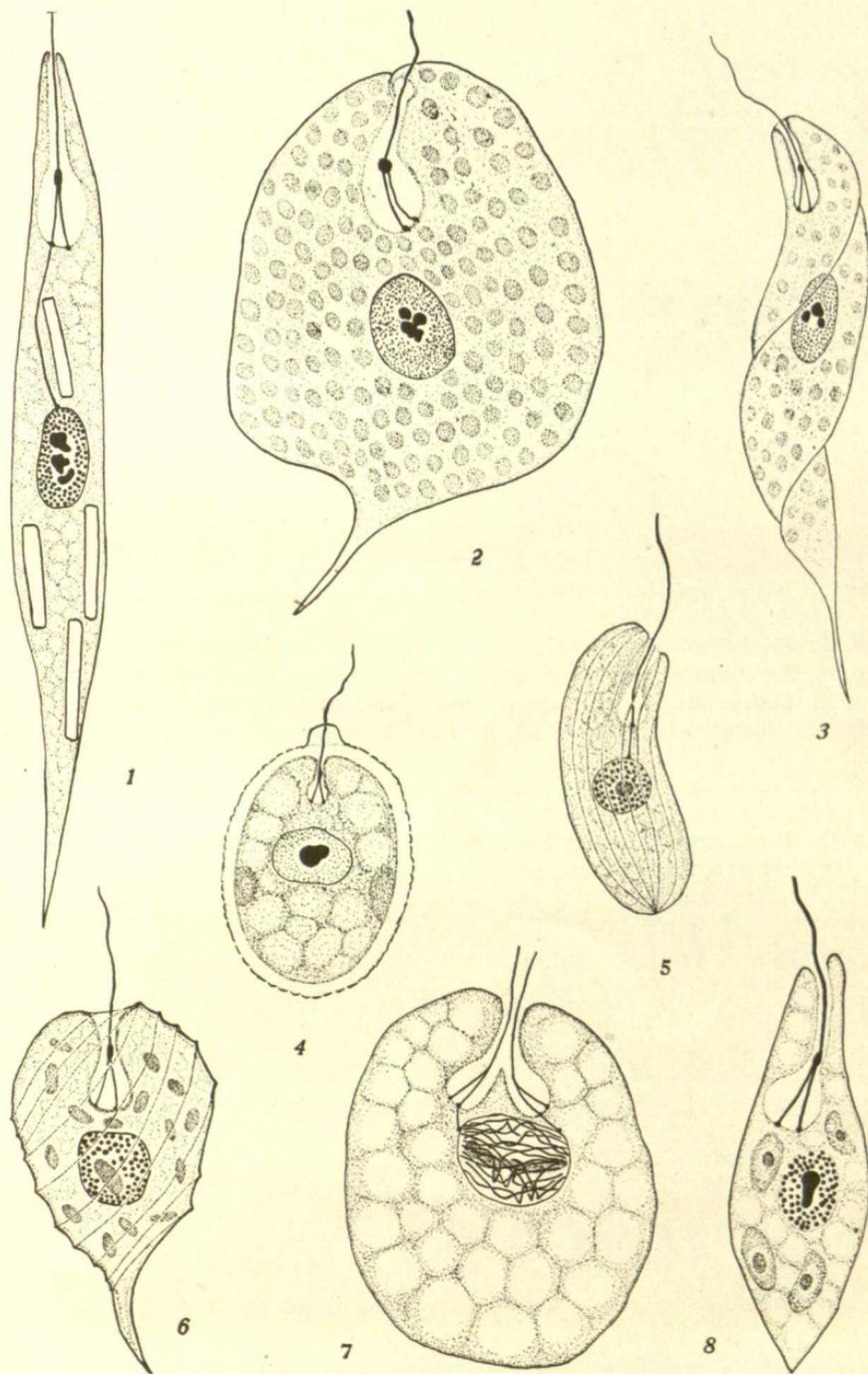


PLATE XLVII

PLATE XLVIII

- FIG. 9. *Euglena terricola*, flagellar structure and chromatophores; from a preparation by R. F. Nigrelli; S-IH-E; $\times 2025$.
- FIG. 10. *Trachelomonas* sp., flagellar structure; S-BR-IH; $\times 1570$.
- FIG. 11. *Euglena spirogyra*, flagellar structure and chromatophores; S-BR-IH; $\times 715$.
- FIG. 12. *Euglena deses*, flagellar structure and chromatophores; S-BR-IH; $\times 2025$.
- FIG. 13. *Trachelomonas abrupta* (?), flagellar structure and chromatophores; S-BR-IH; $\times 2025$.
- FIG. 14. *Astasia dangeardii*, contracted organism; flagellum is non-bifurcated; S-IH-E; $\times 2025$.
- FIG. 15. *Menoidium falcatum*, optical section showing non-bifurcated flagellum and paramylum bodies; surface striations not indicated; S-IH-BR; $\times 1010$ ca.

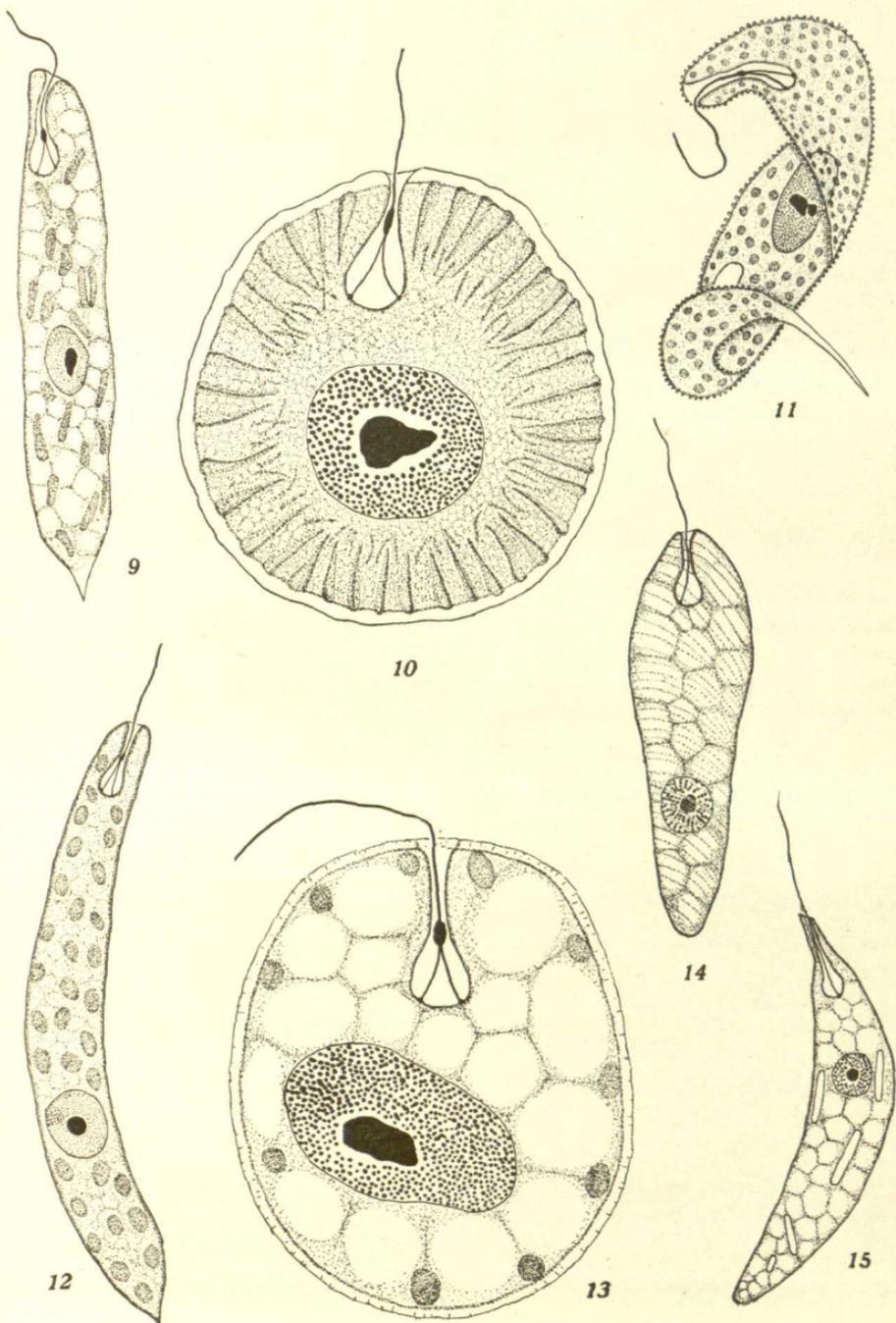


PLATE XLVIII

PLATE XLIX

- FIG. 16. *Lepocinclis ovum*, flagellar structure and chromatophores; S-BR-IH; $\times 3040$.
FIG. 17. *Trachelomonas volvocina*, flagellar structure; S-BR-IH; $\times 2355$.
FIG. 18. *Phacus caudata* (?), flagellar structure; S-BR-IH; $\times 2355$.
FIG. 19. *Lepocinclis ovum* var. *palatina*, flagellar structure; S-BR-IH; $\times 1800$.
FIG. 20. *Phacus pleuronectes*, flagellar structure and chromatophores; oblique optical section; S-IH; $\times 1800$.
FIG. 21. *Euglena granulata* (?), flagellar structure, chromatophores and four pyrenoids shown in optical section; organism partly contracted; S-BR-IH; $\times 1420$.

