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THE SHORTER SCIENTIFIC PAPERS
OF
LEE BARKER WALTON

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LEE BARKER WALTON

THE SHORTER
SCIENTIFIC PAPERS

OF

Lee Barker Walton, Ph.D.

LATE PROFESSOR OF BIOLOGY, KENYON COLLEGE

with an Introduction by

HERBERT OSBORN

Director, Ohio Biological Survey

Edited by

GEORGE P. FAUST

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P R E F A C E

This volume, which has been made possible by the generosity of the Trustees of Kenyon College, was originally intended to contain Dr. Walton's collected publications, but two important studies made for the Ohio Biological Survey were found to be too long for inclusion. Also omitted, because of their subject-matter, are an article "Fraternities and Scholarship" and a newspaper letter on the Flood. On the other hand, a youthful letter of advice about army worms and a proposed etymology of caribou have been rather arbitrarily included.

Reproduction of the figures which accompanied the original articles proved to be impossible. Parenthetical references to them have been cut out, but not references which form part of the text. My hope is that most of the remaining inconsistencies are referable to the original published source.

At the time of his death, Dr. Walton was preparing a collection of his papers; his bibliography has been used as a basis for mine. It was not, however, complete, and the additions I owe to Dr. Herbert Osborn, director of the Ohio Biological Survey and a dear friend of Dr. Walton. I wish to thank Dr. Osborn for his invaluable help and advice in preparing this volume, and for his kindness in writing the Introduction to it.

LEE BARKER WALTON—AN APPRECIATION

Lee Barker Walton was born at Bear Lake, Pa., November 11, 1871, and died at Kenyon College, Gambier, Ohio, May 15, 1937.

My acquaintance with him began at a meeting of the Ohio Academy of Science in December, 1902, when his discussion of certain papers impressed me with his penetrating observation and logical statement. The friendship there begun remained unbroken through the years. I welcome the opportunity to pay tribute to his memory.

Of his boyhood life I have scant personal knowledge. He never talked much about his own experiences but I have gathered from various sources the impression that he grew up under favorable conditions for the foundation of the scholarship so evident in his later career.

From a letter by his sister I learn that he was born on a farm eight miles from the city of Corry, Pa., and entered school at that city in the third grade, going through the grades and two years in high school and two years of college preparatory at Keuka College, New York (near Penn Yan). She writes:

"At about ten years of age he began collecting moths and butterflies. Through a friend he obtained the address of an entomologist in Canada and from him received much help and encouragement in this line of work. At one time he had over a thousand mounted bugs and beetles, some very rare specimens. By exchanging, his collection became very good. His chief occupation during vacations was the collecting of these bugs and beetles. His sister, some years younger, often accompanied him and learned to fear no insects.

"From the time he learned to read he was an inveterate reader and by his actions showed he would rather read than do anything else. When boys came to play, nearly always after a short time he would be missing. They

would find him reading with such intense interest he would not notice them. His family provided good reading but he would read everything he could find.

"Although born on a farm he was never very much interested in farm life and seldom cared to do farm work. I remember one time when father wanted him to drive the horses on the mowing machine. The field was a large one with woods bordering one side. Nearly every time around the field when he would come to the woods he would leave the horses standing and go into the woods and hunt for bugs. When father spoke to him about it he replied that the horses needed the rest."

In a letter from an early teacher we learn that "He was my pupil at 6 years of age. A bright, sturdy little lad in high red top rubber boots. Nature study and trout fishing were of special interest to him and he would roam the tamarack swamp and wilds of Sulphur Springs territory alone with great pleasure and wonderment. He was very proud of his capture of a loon and had it mounted by a taxidermist. . . . His collecting and mounting butterflies and insects was so pronounced that the whole community was amazed."

He doubtless passed through the various grades of elementary and secondary schools required as a preparation of entry to Cornell University, where he entered in 1893 and graduated with the degree of Bachelor of Philosophy in 1897.

His further preparation for a scientific career is summed up briefly in the obituary note by the writer in *Science* for July 15, 1938, from which I quote:

"Later he spent the years '98 and '99 in Germany—except for six months in India where, according to Mrs. Walton, 'he was interested mostly in collecting butterflies and beetles'. We may question this since Caroline Louise Graham, the daughter of a Missionary to India, later became Mrs. Walton. He went to Brown University in 1899 and served as Assistant to Dr. A. S. Packard in 1900-1901, while working for the Ph.D. degree. He studied at Woods Hole during the summer of 1901 and was assistant to Dr. Bumpus at the American Museum of Nat-

ural History 1901-1902. He was Goldwin Smith Fellow and secured his Ph.D. at Cornell University in 1902 and that fall began his notable career at Kenyon College, Gambier, Ohio, where he remained an outstanding figure until his untimely death. In this position he at once identified himself with the Ohio Academy of Science and became one of its most loyal members, serving as Secretary, President and on various principal committees”.

He was married to Caroline Louise Graham at Sangli, India, March 1, 1898, and five children were born to them. Harold Graham, born Nov. 13, 1898; Robert Barker, born March 13, 1900, died August 13, 1916; Margaret Bai, born August 21, 1902; Graham, born January 22, 1906; Roger Lee, born July 22, 1914. Harold graduated from Kenyon College in 1920, Margaret graduated from Wellesley, 1924, Graham from Kenyon College in 1927 and from Mass. Inst. Technology in 1930; Roger graduated from Kenyon College in 1935. While none of the children have followed the father in the field of biology, all are filling important places in society, Harold in the field of actuarial insurance, Margaret as the wife of Dr. Faust of Knox College, Galesburg, Ill., Graham as instructor in sanitary and hydraulic engineering in the University of Wisconsin, and Roger with the teaching profession in view.

During the summers of 1905, '06, '07 and '09 he taught courses in biology at the Lake Laboratory, located then on Cedar Point near Sandusky, and his enthusiasm and broad training were an inspiration to both staff and students. The intimate associations in this connection naturally resulted in a close friendship which persisted through the years.

With other members of the Ohio Academy of Science he was instrumental in the organization of the Ohio Biological Survey as a Department of the State University and served on its Advisory Board from its establishment to his death. In this connection he carried on studies, mainly on aquatic organisms, and the results of his studies appeared in two important papers, "The Euglenoidina of Ohio" and "Studies Concerning Organisms Occurring in

Water Supplies", both being much in demand from outside Ohio as well as here.

He held membership in a number of National Scientific Societies, among them Botanical Society of America, American Society Zoologists, American Society of Naturalists, Boston Society Natural History and Entomological Society of America. He was Fellow of American Association for the Advancement of Science and a member of the council, 1915-17. He was a member of the Honorary Societies of Sigma Xi and Alpha Tau Omega.

His interests were varied—not confined to his Biological work—and he was particularly interested in out door sports for young men, tennis, golf, hiking, fishing, and said "more of that kind of interest would tend to keep the young men in the proper condition morally as well as physically". He was "a great believer in play as well as work".

He was interested in problems of evolution and many of his published papers had a bearing upon various phases of these fundamental biological questions. A good example of his originality of thought and method of attack on a problem is shown in his studies of the phenomena of spiral movement in aquatic organisms as exhibited in regions north and south of the equator where the spiral movement has a reverse rotation in forms he observed. The intricate structure of various arthropod groups and their bearing on the questions of their phylogenetic affinities formed the subject of a number of morphologic studies.

He was a successful teacher, beloved by his students, many of them going on to successful careers. Here perhaps was his greatest contribution to science and society—a contribution which cannot be estimated in any statistical or analytical terms.

Walton had the happy faculty of making friends with people in many different ranks of society and it was remarked of him by a close friend that he was "an aristocrat and a democrat". He liked to associate with people high up and could also be found in a garage playing checkers with some of the garage men.

He also had the facility to accomplish much with apparently little exertion. One of his close friends says "Lee accomplished more with the least apparent effort of any one I have ever known". This facility was no doubt in large part due to his ability to see the important thing and to eliminate waste motion.

It would be interesting to enlarge upon his interest in national and international affairs as he always had definite and original ideas to present in such matters. I do not think he ever carried the idea that his own view was the only one to be considered or that his opinions must be accepted without debate. Altogether as I think back over the many years of our association I am the more impressed with the constructive and beneficent nature of his life. He must have been a strong contributing factor in the community as well as in the college circle where so large a part of his life was spent.

Personally the writer thinks of him as an admired companion, a wholesome nature full of the joy of life and capable of firing the enthusiasm of students and associates in the pursuit of knowledge, making serious work a joyful occupation. His friendship through the years is one of the treasured memories of life.

HERBERT OSBORN.

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LIST OF COLEOPTERA COLLECTED IN THE VICINITY OF KEUKA COLLEGE*

The species given in the list below form but a small part of the fauna found in the central part of New York belonging to this order, and were collected in a single season; nevertheless it has been thought best to mention the material thus accumulated. Thanks are due to Mr. Charles Liebeck, of the Academy of Natural Sciences at Philadelphia, for the determination of specimens which were new to the compiler of this list. Sincerely trusting that many additional species may be noted in later years, this unpretentious beginning is submitted.

<i>Cicindela 6-guttata</i> ,	<i>Lebia atriventris</i> ,	<i>Staphylinus maculosus</i> ,
<i>Cicindela purpurea</i> ,	<i>Lebia viridis</i> ,	<i>Staphylinus cinnamopterus</i> ,
<i>Cicindela vulgaris</i> ,	<i>Lebia ornata</i> ,	<i>Staphylinus violaceus</i> ,
<i>Cicindela 12-guttata</i> ,	<i>Dromius piceus</i> ,	<i>Philonthus aeneus</i> ,
<i>Elaphrus ruscarius</i> ,	<i>Cymindis cribricollis</i> ,	<i>Philonthus fusiformis</i> ,
<i>Nebria pallipes</i> ,	<i>Brachynus cordicollis</i> ,	<i>Paederus littorarius</i> ,
<i>Dyschirius nigripes</i> ,	<i>Chlaenius sericeus</i> ,	<i>Geodromicus nigrita</i> ,
<i>Bembidium undulatum</i> ,	<i>Chlaenius leucoscelis</i> ,	<i>Arpedium cribratum</i> ,
<i>Bembidium pictum</i> ,	<i>Chlaenius tricolor</i>	<i>Olophrum rotundicolle</i> ,
<i>Bembidium quadrimaculatum</i> ,	<i>Chlaenius Pennsylvanicus</i> ,	<i>Megilla maculata</i> ,
<i>Tachys proximus?</i>	<i>Harpalus viridiaeneus</i> ,	<i>Hippodamia 13-punctata</i> ,
<i>Tachys nanus</i> ,	<i>Harpalus caliginosus</i> ,	<i>Hippodamia parenthesis</i> ,
<i>Patrobus longicornis</i> ,	<i>Harpalus Pennsylvanicus</i> ,	<i>Coccinella 9-notata</i> ,
<i>Pterostichus adoxus</i> ,	<i>Harpalus erraticus</i> ,	<i>Coccinella sanguinea</i> ,
<i>Pterostichus rostratus</i> ,	<i>Stenolophus fuliginosus</i> ,	<i>Adalia bipunctata</i> ,
<i>Pterostichus honestus</i> ,	<i>Anisodactylus melanopus</i> ,	<i>Chilocerus bivulnerus</i> ,
<i>Pterostichus Sayi</i> ,	<i>Anisodactylus lugubris</i> ,	<i>Brachyacantha ursina</i> ,
<i>Pterostichus lucublandus</i> ,	<i>Gyrinus analis</i> ,	<i>Scymnus punctatus</i> ,
<i>Pterostichus luteus</i> ,	<i>Hydrophilus triangularis</i> ,	<i>Aphorista vittata</i> ,
<i>Pterostichus mutus</i> ,	<i>Hydrocharis obtusatus</i> ,	<i>Mycetina testacea</i> ,
<i>Pterostichus patruelis</i> ,	<i>Necrophorus orbicollis</i> ,	<i>Tritoma biguttata</i> ,
<i>Evarthrus sodalis</i> ,	<i>Necrophorus marginatus</i> ,	<i>Tritoma thoracica</i> ,
<i>Amara fallax</i> ,	<i>Necrophorus pustulatus</i> ,	<i>Cerylon castaneum</i> ,
<i>Amara obesa</i> ,	<i>Necrophorus tomentosus</i> ,	<i>Silvanus bidentatus</i> ,
<i>Calathus gregarius</i> ,	<i>Silpha surinamensis</i> ,	<i>Silvanus planatus</i> ,
<i>Platynus hypolithus</i> ,	<i>Silpha lapponica</i> ,	<i>Silvanus advena</i> ,
<i>Platynus angustatus</i> ,	<i>Silpha noveboracensis</i> ,	<i>Catogenus rufus</i> ,
<i>Platynus extensicollis</i> ,	<i>Liodes basalis</i> ,	<i>Cucujus clavipes</i> ,
<i>Platynus atratus?</i>	<i>Agathidium oniscoides</i> ,	<i>Laemophlaeus fasciatus</i> ,
<i>Platynus cupripennis</i> ,	<i>Aleochara sp.</i> ,	<i>Laemophlaeus convexulus</i> ,
<i>Platynus nitidulum</i> ,	<i>Listotroplus cingulatus</i> ,	<i>Telephanus velox</i> ,
<i>Galerita janus</i> ,	<i>Creophilus villosus</i> ,	<i>Atomaria ephippiata</i> ,
<i>Lebia grandis</i> ,	<i>Staphylinus vulpinus</i> ,	<i>Epuraea truncatella</i> ,

*Reprinted from the *Keuka College Record*, June, 1892.

Nitidula bipustulata,	Dorcus parallelus,	Leptura nitens,
Ips fasciatus,	Platycerus quercus,	Lepturges symmetricus,
Ips sanguinolentus,	Copris anaglypticus,	Saperda lateralis,
Ips confluentus,	Aphodius fimetarius,	Saperda moesta,
Tenebroides corticalis,	Aphodius inquinatus,	Tetraopes tetraophthalmus,
Alaus oculatus,	Geatrupes splendidus,	Donacia proxima,
Elater nigricollis,	Geotrupes Blackburnii,	Cryptocephalus 4-macutata,
Elater linteus,	Hoplia trifasciata,	Chrysochus auratus,
Agriotes mancus,	Dichelonycha subvittata,	Doryphora 10-lineata,
Corymbites cylindriciformis,	Serica sericea,	Chrysomela saturalis,
Corymbites hieroglyphicus,	Pelidnota punctata,	Gastroidea polygoni,
Chalcophora Virginiensis,	Euphoria fulgida,	Nyctobates Pennsylvanica,
Dicerca divaricata,	Euphoria inda,	Iphthimus opacus,
Dicerca asperata,	Osmoderma eremicola,	Blapstinus metallicus,
Buprestis lineata,	Osmoderma scabra,	Helops micans,
Chrysobothris femorata,	Parandra brunnea,	Chromatia amoena,
Brachys aerea,	Tetropium cinnamopterum,	Hypulus simulator,
Chauliognathus	Phymatodes amoenus,	Anthicus formicarius,
Pennsylvanicus,	Phymatodes varius,	Magdalis pandura,
Cymatodera bicolor,	Chion cinctus,	Centrinus scutellum-album,
Trichodes Nuttalli,	Arhopalus fulminans,	Eupsalis minuta,
Clerus quadriguttatus,	Cyllene robiniae,	Stenoscelis brevis,
Eucrada humeralis,	Acmaeops pratensis,	

CAPTURING BEMBIDIUM AND OTHER SMALL COLEOPTERA*

It may prove a help to some of our numerous Coleopterists to know how to easily collect these active little beetles which are so common along the shores of lakes and rivers. Is there a collector who has not endeavored to pick them up between his (her?) thumb and forefinger and transfer the specimens to the cyanide or alcohol bottle, only to find them *non est* just as he supposes they are safely inside. Here is a method that worked very successfully with me while at Chautauqua, N. Y., during July and August of last summer. Procure a two-drachm vial one-quarter full of chloroform. Now, having found a locality where the beetles are plenty, drop the brush in the ether and apply to the specimens wanted. It is surprising to see how quickly they are put to sleep. Almost immediately they may be transferred to the alcohol bottle on the tip of the brush and you are ready for more. In this manner hundreds may be taken within a short time, and I am sure it would work admirably with the insects of other orders besides Coleoptera, especially where the species are minute, but too quick to take in the usual manner. Try it.

*Reprinted from *Entomological News*, vol. 3 (1892), pp. 155-156.

REGARDING THE IDENTITY OF OXYPORUS RUFIPENNIS AND STYGICUS*

LeConte, in his paper on certain genera of Staphylinidae Oxytelini, etc. (Trans. Amer. Ent. Soc. vi, October, 1877), says in reference to *Oxyporus rufipennis* Lec.: "This is perhaps only a color variation of the entirely black *O. stygicus* Say, but as yet I have seen no intermediate specimens. There is no difference in form or structure."

A year ago last summer, while doing some collecting at Bear Lake, Pa., I took a large number of both *stygicus* and *rufipennis*, and also what appeared to be an intermediate form having the elytra black with two yellow vittae plainly evident on each elytron. The occurrence of this form, together with the fact that all were taken on the same piece of fungus, would seem to bear out LeConte's supposition as to *rufipennis* being merely a variety of *stygicus*. Having sent some specimens to Dr. Horn, he says: "While I believe the two are one species, something more than an opinion is required to corroborate it," referring to the fact that it would be necessary to take them *in coitu* to bring in the conclusive proof.

*Reprinted from *Entomological News*, vol. 5 (1894), p. 13.

THE ARMY WORM*

Owing to the appearance of the army worm in the vicinity, some information concerning its habits and the best methods of preventing its ravages may prove of interest.

This pest is the larva of a small moth, *Leucantia unipuncta*, and receives the name "army worm" because after destroying vegetation in the field where the eggs are laid marches like an army to other fields. It occurs throughout the United States east of the Rocky Mountains every year, but attracts attention only when present in large numbers.

The eggs are laid in the Fall by the parent moth and the worm, which is one and one-half inches long when full grown, striped with yellow, black, and green, attains its growth the last of June or the early part of July. Nearly all forage crops are subject to its attack and from the fact that leaves and stems are cut off the damage done is far greater than the loss of the portion which is eaten.

The most of the injury is done at night while during the day the majority of the worms remain at the surface of the ground.

If the worm is discovered before it has spread it can be prevented from its journeyings by surrounding the field with a ditch, since it is impossible for the worm to ascend the steep vertical side. It is well to dig holes, like post holes, at intervals of a few rods in such ditches. The worms falling into the ditch have difficulty in getting out and crawling along the bottom fall into the deeper holes where they perish. They can also be destroyed by spraying with Paris Green, but it would probably be more consistent to save the crop by cutting early.

"Q"

*Reprinted from the Bear Lake (Penna.) *Record*, August 15, 1896.

THE BASAL SEGMENTS OF THE HEXAPOD LEG*

At the base of each leg in the Hexapoda are a series of segments and sclerites which enter into the composition and serve as a support of the appendage. These are the trochanter, *coxa genuina*, meron¹ trochantin, and antcoxal piece. The difficulties in the way of accounting for the origin of these segments and homologizing them in the various orders have caused morphologists more or less trouble.

By reason of the fusion which has taken place between the trochanter and femur in the Myriopoda and Hexapoda, many writers on insect anatomy hold that the trochanter is merely a portion of the femur which has in some manner become constricted so as to form an apparent but not an actual segment. The fusion, however, between the two parts is a specialization acquired during the later embryonic stages of development.² A similar case of ankylosis is often noticeable between certain segments of the appendages in Crustacea. Bordage³ has advanced the theory, from observations based on certain Phasmidæ, that the two segments have become coalesced in the Arthropoda as a result of ecdysis. Since the same fusion, however, is very pronounced in the Myriopoda, particularly among the Diplopoda, where Verhoeff⁴ believes the trochanter is in many cases entirely absent, it is

¹ In order to distinguish between these two parts, which have been confused under the name "coxa," I have called the piece articulating with the trochanter *coxa genuina*, and the posterior lateral part articulating with the epimeron, meron (from *μηρός* = thigh), since its lateral margin is always found in articulation with the epimeron.

² The "two-jointed trochanter" of Hymenoptera [Terebrantia] appears to be a secondary modification, the lower part ["*apophysis*," Ratzeburg] being derived from the femur. This is the view held by Sharp, *Camb. Nat. Hist.*, vol. v, p. 520.

³ On the Probable Mode of Formation of the Fusion between the Femur and Trochanter in Arthropoda. *Comptes Rendus de la Société de Biologie*, tome v, No. 28, pp. 839-842, 1898. Also *Ann. and Mag. Nat. Hist.*, vol. iii, pp. 159-162, 1899.

⁴ Ein Beitrag zur Kenntniss der Glomeriden. 1895.

*Reprinted from *The American Naturalist*, vol. 34 (1900), pp. 267-274.

evident that it is a characteristic of a primitive stem form, and has not arisen, as Bordage suggests, from an "ancestral form belonging to the existing Phasmids in which there was a distinct articulation between the two consecutive segments."¹ In addition to ecdysis, insisted upon by Bordage,² we must take into consideration various other selective factors, chief among which appear to have been mutilations by enemies. The severing of the segments, which resulted from either factor, would probably occur near the base of the appendage, and the favored forms would be those in which the two segments were approaching the fused condition, the invagination of the chitinous wall preventing undue hemorrhage. Autotomy, which Bordage so fully explains, would undoubtedly play an important part here. It also appears advantageous to polypodial forms that a series of the appendages move more or less in unison, and it is obvious that such rhythmic motion is better maintained with the articulation of a coxa and trochanter alone than with an additional articulation between the trochanter and femur. This may be a factor in accounting for the more pronounced fusion of the two segments in the Diplopoda.

In 1893 Hansen³ endeavored to homologize the trochanter of the Hexapoda with the ischiopodite in Crustacea. This homology was based on the supposition that the part assumed by him to be the trochantin⁴ in the Cicadaria (Cicadidæ, Fulgoridæ, Cixidæ, etc.) was the homologue of the coxopodite in Crustacea. In referring to Machilis, he has considered the trochantin of the prothoracic coxa as a primary segment, homologous with the coxopodite. From comparisons, however, with both Chilopoda and Diplopoda, we would regard the trochantin rather as a specialized character of the Hexapoda, which

¹I have adopted the translation as given by Austen.

²The position of Bordage in regard to the manner in which the fusion has come about is clearly on the side of Neo-Lamarckianism, since he attributes it to "a mechanical strain," and says that it is an "example of a character acquired by use . . . and then transmitted by heredity." This conclusion, however, as I have endeavored to show, seems unwarranted.

³Zur Morphologie der Gliedmassen und Mundtheile bei Crustaceen und Insecten. *Zool. Anz.*, pp. 193-198, 201-212, 1893.

⁴It seems probable that Hansen has here applied the name "trochantin" to the antecoxal piece and trochantin together.

is absent in the Crustacea. Homologies based upon the form of the segment and manner of articulation certainly appear questionable, since pronounced variations often occur within the limits of a single group.¹

Until a closer relationship can be shown in the lines of descent of the two groups, Hexapoda and Crustacea, it would seem that an attempt to homologize the segments of the appendages would scarcely be justified. For the time being, we must assume that the segmentation of an appendage is a result brought about by certain indefinite factors, and that in these groups it does not necessarily imply a phylogenetic relationship.

That the trochanter of the Myriopoda and Hexapoda represents a distinct segment seems obvious, and that its fusion with the femur took place in some ancestral myriopod-like form appears probable.

Three sclerites, as a rule, enter into the composition of the segment to which the name coxa is given, *viz.*, *coxa genuina*, meron, and trochantin. Audouin² applied the name "trochantin"³ to the lateral margin of the posterior coxa (meron) in *Dytiscus circumflexus*, erroneously believing it homologous with the trochantin on the anterior and mesal coxæ⁴ of *Buprestis gigas*, which he subsequently mentions.⁵ Later, in his contribution to Cuvier's "Le Regne Animal," he figures the prothoracic trochantin of *Oryctes nasicornis*. The present confused terminology of these segments is due to the preceding error of Audouin. Newport⁶ made a somewhat similar error by describing the anterior margin of the coxa (*coxa*

¹Compare Arachnida, or, in Coleoptera, the metathoracic coxa of *Dytiscus* and *Hydrophilus*.

²Recherches anatomiques sur le thorax des animaux articulés et celui des insectes hexapodes en particulier. *Ann. Sci. Nat.*, tome i, p. 125, 1824.

³This word had been previously used by Chaussier [*Littre, Dict. de Médecine*, p. 1632] during the latter part of the eighteenth century to designate a small process on the upper part of the femur in the human skeleton. From the note Audouin appends, he evidently felt some constraint in conforming to the custom of transferring such terms to invertebrate anatomy when no homologies could be demonstrated.

⁴In the metathorax of the Coleoptera the trochantin has been lost through specialization, although traces of it are noticeable among many forms (*Hydrophilus*, certain *Cerambycidae*, etc.).

⁵Étude de la poitrine ou des pattes inférieures et latérales du mesothorax. *Ann. Sci. Nat.*, tome i, p. 426, 1824. This is merely a continuation of Recherches anatomiques.

⁶Todd's *Cyclopedia of Anatomy and Physiology*, p. 916, 1835-59.

genuina) in *Hydrous piceus*, as the metathoracic trochantin. Among the recent writers on insect anatomy, Packard¹ confuses the trochantin with the meron; Miall and Denny³ hold that the occurrence of the joint applied to the coxa (trochantin) "is so partial" that it need scarcely be taken into consideration; Sharp² believes with Packard that the posterior part of the coxa (meron) in *Panorpa* represents the trochantin; while Comstock,⁴ in a description of the metathorax in *Euchromia gigantea*, agrees essentially with the preceding, although he correctly figures the trochantin of the prothorax and mesothorax. Lowne⁵ regards the piece termed by him "epitrochlea"⁶ as "certainly the trochantin of Audouin," ignoring his previous suggestion that one should adhere to the rule of priority. Several other writers, notably Latzel (Chilopoda), Comstock and Kellogg (Lepidoptera), and Kolbe (Lepidoptera, Trichoptera, and *Panorpa*), have mentioned the existence of an apparent suture in the coxa of certain groups under consideration, but without attempting to discuss its meaning.

Immediately in front of the metathoracic coxa, particularly among the Coleoptera, a small sclerite is discernible, which bears the name of antecoxal piece. This is also well shown in *Cicada*, some species of which (*Cicada dorsata*) possess a piece homologous with that found in the Coleoptera; while in others (*Cicada tibicen*)⁷ instead of being chitinized, the part is often membranaceous in structure, and serves to retain the coxa more firmly in the coxal cavities, thus indicating its origin; and the presence of a homologous piece in the mesothorax of many Coleop-

¹Systematic Position of the Orthoptera in Relation to the Orders of Insects. *Third Report U. S. Ent. Com.*, 1880-82. *A Text-Book of Entomology*, p. 95, 1898.

²The Structure and Life History of the Cockroach, p. 61, 1886.

³*Camb. Nat. Hist.*, vol. v, p. 104, 1895.

⁴Manual for the Study of Insects, p. 504, 1895. It was due to Professor Comstock's suggestion of a possible error in considering the lateral margin of the metathoracic coxa of *Euchromia* as the actual homologue of the mesothoracic trochantin, that the study leading to this paper was commenced.

⁵The Anatomy, Physiology, Morphology, and Development of the Blow-Fly, vol. i, p. 179, 1890-92.

⁶The homology of this with the trochantin appears doubtful.

⁷Although a good series was examined in which the other sclerites were well chitinized, the absence of chitinization in the antecoxal piece may be the result of immaturity. This, however, would not alter the conclusion.

tera (Passalus, etc.), occurring at the same time with the trochantin, proves that it is distinct from the latter.

The *origin* of the three pieces, *coxa genuina*, meron, and trochantin, the relative positions of which are shown in the accompanying figures, is more difficult of explanation. A striking characteristic of the Hexapoda and Chilopoda is the more or less complete fusion of the first two (*coxa genuina* and meron) into the so-called coxa. Theoretically the episternum¹ and epimeron may be regarded as corresponding basal segments of these fused pieces, and taking into consideration the apparent absence of a piece homologous with the meron in the Diplopoda, we are led to the interesting inference that this group represents a class in which *each primitive metamere bears a pair of appendages*, while the Chilopoda and Hexapoda represent a widely divergent class, in which *two primitive metameres have attained a more complete fusion*,² *the rudimentary appendage belonging to each posterior segment fusing with the base of the functional appendage belonging to the anterior metamere*.³ The posterior appendage would then be represented by the meron and epimeron.⁴ In this case we can refer the origin of *coxa genuina* and episternum, as well as the meron and epimeron, to the same causes which produce segmentation in the appendage. The trochantin appears to be nothing more than a part of the antecoxal piece, a lateral prolongation of which became constricted off in a primitive form. Again we are confronted with the question as to the origin of the appendages in the Arthropoda, whether they are ventral or dorsal parapodia, or a fusion of the two, as in Nereis, or whether the origin was entirely independent of the parapodia. A study of Peripatus appears to throw no light

¹Frequently the episternum appears to be cut off from the coxa by the sternum or by the trochantin, but in such cases the coxa is usually prolonged internally, so that it meets the episternum.

²At present there appears to be better evidence for believing that these pieces indicate a fusion of the segments than to hold that an exopodite and entopodite are represented.

³A study of the position and homologies of certain of the pleural and dorsal sclerites in Hexapoda and Chilopoda appears to confirm this inference.

⁴While thus far the majority of embryological evidence appears to be against this view, it seems possible that secondary modifications have caused a misinterpretation of the lines of descent.

on the subject under discussion, beyond indicating that in using the term "primitive metamere" we must not exclude the idea that such a metamere may in turn represent a fusion of an indefinite number of annuli. Evidence is thus added to a segment-fusion theory rather than to the biramous theory.

While it appears possible that the exopodite and entopodite in Crustacea may have developed from dorsal and ventral parapodia, in direct contrast to the manner indicated above for the Chilopoda and Hexapoda, further study may show a common origin of the two processes.

SUMMARY

In Hexapoda and Chilopoda the "coxa" is composed of two more or less fused segments, *coxa genuina* and meron.

The antecoxal piece results from the chitinization of the membrane connecting the coxa with the sternum.

The trochantin probably originated from a lateral portion of the same membrane.

Audouin erroneously homologized the lateral margin of the posterior coxa in *Dytiscus circumflexus* with the trochantin of the prothorax and mesothorax.

The trochanter represents a distinct segment of the legs.

The meron and *coxa genuina*, together with their corresponding basal segments epimeron and episternum, give evidence of a fusion between two primary metameres in the Hexapoda and Chilopoda.

In Hexapoda and Chilopoda the anterior metamere bears the functional, and the posterior, the rudimentary leg.

Of the primitive Hexapoda, Neuroptera [Planipennia] exhibit the most generalized condition in the development of the coxa, while in Thysanura and Orthoptera a high degree of specialization is shown.

THE METATHORACIC PTERYGODA OF THE HEXAPODA AND THEIR RELATION TO THE WINGS*

On the anterior margin of the prothorax and mesothorax of the Lepidoptera are two small sclerites known as the patagium and tegula, respectively; while in certain other orders of Hexapoda (Hymenoptera, Neuroptera, and Trichoptera) a small piece has been found at the base of the mesothoracic wing which has been considered equivalent to the tegula. Further than a few suggestions based on limited observations, no attempt has been made either to ascertain the value of these pieces or to demonstrate the existence of similar homodynamous or homologous structures in the hexapods.

The purpose of the present paper is to call attention briefly to the general presence of a sclerite on the hexapod metathorax which seems homodynamous with the so-called tegula, to make some suggestions concerning terminology, and especially to point out that the present view concerning the metamerism of the antennate arthropods appears worthy of reconsideration.

The relation of the tegula, or pterygodum as I prefer to term it, to the pieces of the mesothorax, which is in many respects the most generalized of the three thoracic segments in the insects, is shown in Fig. 1. Bearing in mind now that the mesothorax and metathorax are equivalent, the various components of each being reduplicated in the other segments, subject, however, to the factors governing the specialization of the different groups of insects, the existence of a corresponding piece in the metathorax would *a priori* be inferred. The presence of such a piece¹ is represented in the accompanying diagram,

¹From comparisons made throughout the Hexapoda it is evident that this does not correspond to the more or less chitinized part of the epimeron at the base of the wing in most Lepidoptera.

*Reprinted from *The American Naturalist*, vol. 35, no. 413 (1901), pp. 357-362.

while a homologous part can generally be demonstrated throughout the other orders. Furthermore, it is to be noted that in the typical form this is joined to the dorsal margin of the episternum, while the wing is articulated with the dorsal margin of the epimeron and not, as hitherto accepted, with the episternum.¹

In connection with the facts noted above, certain evidence is available, based on embryology as well as comparative anatomy, which adds weight to the inference that these two pieces are rudimentary² wings and that the *thorax of the Hexapoda is composed of six somites which in the typical form bear the fundamentals of six pairs of wings*.

The development of the mesothoracic pterygodum³ (= tegula, parapteron, etc.) is of extreme interest in this connection and furnishes interesting evidence toward establishing the hypothesis I have put forward regarding its relation to the wing. This, however, is only one of a large number of facts which corroborate such a view and which appear explainable on no other basis. To one of these I have already called attention (Walton, 1900), notably the formation of the coxa in Chilopoda and Hexapoda from two fused pieces to which I have applied the name "coxa genuina" and "meron."

I have adopted the name "pterygodum"⁴ for the present in preference to others which have been suggested for the mesothoracic piece (tegula, parapteron, squamula, etc.), since it has priority over terms otherwise acceptable, and according to our present knowledge better indicates the function of the part. The term "parapteron," which Comstock and Needham ('98), following Newport ('39), have used in reference to the mesothoracic pterygodum,

¹The anterior margin of the wing is generally specialized at the base, so that it partially extends over the dorsal portion of the episternum, while an articulative process of the pterygodum may be received into a corresponding notch of wing. This condition, however, is secondary.

²There appears to be no evidence for regarding these as vestigial, since it is improbable that forms with six pairs of wings ever existed. The term "rudimentary," as generally used, does not seem inappropriate, although the word "fundament" is more concise.

³Owing to its greater size, this can be more conveniently studied than the corresponding piece on the metathorax.

⁴<gr. περιγώδης < περιγοειδής = πτέρυγος [wing] + εἶδος [form].

appears inappropriate, for the reason that Audouin ('24) first used it to indicate a supposed sclerite on the anterior margin of the mesothoracic episterna in *Dytiscus circumflexus*, the part in question being merely an articulative process. Several years later, in a note to a translation of a paper by MacLeay ('32), Audouin stated his belief that the piece in the Hymenoptera termed squamula by MacLeay was homologous to the parapteron which he himself had described. This supposition was not only incorrect but was subsequent to the terminology adopted by Latreille.

The value of the patagium on the prothorax has been more or less discussed, but until we know more concerning its development it is impossible fully to decide whether it is equivalent to the wing, as suggested by Chlodkowsky ('86), or to the pterygodum (tegula), the view adopted by Haase ('86) and now so generally accepted. It should be observed, nevertheless, that the reasons given by Haase for reaching such a conclusion are far from adequate, since the only evidence to which he called attention, other-wise than a superficial resemblance, was that (1) chitinous folds of a similar nature but of secondary origin are present on the prothorax of certain Hymenoptera and Diptera, while (2) the patagia do not exist during the larval stage of the Lepidoptera, but commence their development in the first few days of the chrysalid stage. Unfortunately, however, Haase failed to demonstrate any homologous structures in the Hymenoptera or Diptera, and had he attempted to do so it is evident, from the preceding, that proof of their secondary nature would have been difficult to establish. Moreover, the Anlage of a structure must exist *in potentio*, and the time during the post-embryonic stages at which it commences that which is known as development can alone be of no particular value in determining its palingenetic or cenogenetic character. The question as to whether the patagium represents a prothoracic pterygodum or a wing, must await a large amount of comparative work based on embry-

ology, with the possibility of paleontological¹ evidence affording some help in the solution of the problem. The ratio of development between wing and pterygodum on the other thoracic segments allows the inference, however, that pterygoda may exist in front of the patagia which then have the value of wings.

Another interesting question in this connection is the homology of the elytra of Coleoptera, for again further investigation must be awaited before a logical conclusion can be reached. The tracheation of the elytra, to which attention has been called by Comstock and Needham ('98), is not conclusive evidence that they are specialized wings, for in connection with the view I have here advocated this would be expected if they were homologous with the mesothoracic pterygoda of the Lepidoptera, and the suppressed wing was represented by the alulet so noticeable under the Elytra in *Hydrophilus*, etc.

From the preceding facts, to which I have called attention, it appears necessary to consider that the typical thoracic segment possesses the components of both pterygodum and wing, the former joined to the dorsal margin of the episternum, the latter articulated with the dorsal margin of the epimeron, while furthermore the morphological position of the pterygodum in respect to the wing indicates that it may have an important bearing in elucidating the metamerism of the antennate arthropods.

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¹The prothoracic appendages of certain fossil insects (*Homoioptera woodwardi*, *Stenodicta lobata*, *Lithomantis goldenbergi*, *carbonaria*, etc.) so excellently figured by Brongiart (*Recherches pour servir à l'histoire des insectes fossiles*, Paris, 1894) cannot be homologized with the expanded margin of the prothorax in existing Mantidæ, as Woodward (*Quart. Journ. Geol. Soc.*, vol. xxxii, p. 60, London) suggested. Brongiart has already pointed this out. (Note sur quelques insectes fossiles du terrain houiller qui présentent au prothorax des appendices aliformes, *Bull. Soc. Philom.*, tome ii, 1890.)

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THE ARRANGEMENT OF THE SEGMENTAL
MUSCLES IN THE GEOPHILIDÆ, AND ITS
BEARING UPON THE DOUBLE NATURE
OF THE SEGMENT IN THE HEXAPODA
AND CHILOPODA*

The arrangement of the dorsal lateral longitudinal muscles in the Geophilidæ corresponds to the division of the segment into an anterior and posterior somite. This, considered in connection with the presence of homologous areas in *Scolopendrella*, *Campodea*, *Japyx*, *Forficula*, etc., together with other evidence, notably the development of the pterygodum (tegula) and wing of the mesothorax in Lepidoptera, the double cross commissures in the embryonic stages of Hexapoda and Chilopoda (as well as Crustacea and Arachnida), the two pairs of metathoracic tracheal openings in *Japyx*, etc., presents a strong case for regarding the segment in the Hexapoda and Chilopoda as composed of two somites, for which the terms *protosomite* and *deutosomite* are proposed.

The 'microthorax' to which Verhoeff has recently called attention as a fourth thoracic segment anterior to the prothorax (Dermaptera) can not be homologized, as he suggests, with the segment bearing the poison claws in Chilopoda, inasmuch as this segment is composed of a protosomite and deutosomite, the former being homologous with the microthorax (see Geophilidæ). Furthermore, a protosomite homodynamous with the 'microthorax' is present in the Dermaptera on the mesothoracic and metathoracic, as well as on the abdominal, segments. Consequently there is evidence for considering that not only is the thorax in Hexapoda composed of six somites, but that each typical segment in the Hexapoda and Chilopoda (Crustacea and Arachnida?) is composed of two coalesced somites.

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THE RELATIONSHIP OF VARIATION TO
ENVIRONMENT IN *CHRYSANTHEMUM*
*LEUCANTHEMUM**

(Abstract)

It is not sufficient to show that a particular species possesses a certain index of variability in a restricted locality. We must attempt to ascertain the component stimuli forming the environment and learn the effect which each group of stimuli has on the variability of the organism in question. Only by so doing can we draw accurate conclusions concerning the factors of evolution.

While natural environment does not furnish us with the best conditions for the solution of the problem, a study of the variability exhibited by two groups of *Chrysanthemum leucanthemum* (the common white daisy) has brought to light some facts of considerable interest.

In a comparison of two groups of 500 each, obtained on the same day from localities less than a mile apart, it was found that the group having the greater nourishment had the greater variability as measured by the "index of variability."

$$\left(\sqrt{\frac{\sum (x^2 f)}{n}} \right)$$

the "average deviation"

$$\left(\frac{\sum (x.f)}{n} \right)$$

and the amplitude or range of variation. Thus the data obtained in this particular study suggest that the difference in variability is dependent on food supply, or, in other words, that chemical stimuli are one of the underlying factors producing variability. This is a conclusion

*Reprinted from *The Ohio Naturalist*, vol. 4 (1904), p. 56.

that has been previously suggested but not definitely established by statistical methods.

It is evident that there is a need for further investigation in this direction on animals as well as plants, for only by the careful application of statistical methods can the fundamental principles of evolution be ascertained.

THE CATALOGUING OF MUSEUM COLLECTIONS*

The system by which specimens are catalogued in most museums of natural history is open to criticism. Insufficient data concerning the collections are buried in bulky volumes or files to such an extent that one may usually be considered fortunate if after a period of several hours the locality and date of collection of a specimen can be ascertained. Notes concerning the name of the person by whom the specimen was identified, date of identification, etc., are rarely present. The task of a systematist wishing to find the material in a given museum belonging to a particular group (phylum, class, etc.), or obtained from a given locality (country, state, etc.) is usually a most difficult and oftentimes an impossible one.

The use of the card index system, the value of which was long since recognized in business methods, will go far toward obviating the difficulties mentioned. A standard card of 4 x 6 inches has proved to be the most serviceable. Following a chronological order the data which should be rendered accessible in an adequately catalogued collection, can be separated into three groups. These are:

(a) *The Accession Catalogue*, arranged numerically, containing a general record of all material received as whole. Consequently one accession card usually covers a large number of specimens.

(b) *The Department Catalogue*, arranged numerically, giving a complete history of each specimen or group of specimens (of a given species) acquired by each department (Zoology, Botany, Anthropology, etc.).

(c) *The Reference Catalogue*, arranged alphabetically, having the names of all specimens (genus and species in Zoology and Botany) in a given department at the top of the card.

The final disposition of each specimen is indicated, consequently it is an easy matter to at once locate any desired material.

*Reprinted from *The Ohio Naturalist*, vol. 4 (1904), p. 62.

While the Department Catalogue is the principal one, the other two are important and represent a comparatively small amount of labor, inasmuch as a single card contains data for a large number of specimens. Classification of material into groups (e. g., Protozoa, Porifera, etc., in Zoology) can be indicated by using cards with appropriate tabs in different positions, while geographical distribution can be represented, if desired, by different colored cards.

A PRACTICAL DISSECTING TRAY*

Various kinds of dissecting trays have been described by Hatschek and Cori, Kukenthal, Dodge, Pratt, Mark, Kellogg and others, all of which, however, are more or less unsuited to general conditions of laboratory work.

A tray which apparently meets all requirements can be made by selecting a suitable china dish, attaching the cloth called "cotton wool" or "cotton flannel" to the bottom, with the smooth side down, by means of LePage's glue, and pouring in a mixture of melted beeswax and lampblack. The glue should previously be allowed to dry at least twelve hours. Furthermore, the dish should be heated slightly above the melting point of the beeswax before the wax is poured in, and then allowing the bottom layers of the wax to harden first. This prevents the separation of the wax from the side of the dish as well as the formation of cracks on the surface. Trays such as described have been in use in the laboratory at Kenyon College for more than a year, and have been found practical in every respect.

*Reprinted from *The Ohio Naturalist*, vol. 4 (1904), pp. 66-67.

A LAND PLANARIAN IN OHIO¹*

The Land Planarians form a subdivision of the class Turbellaria which together with the Trematoda (parasitic flukes), and Cestoda (tape worms) constitute the phylum Platyhelminthes or flat worms. With a very few exceptions the planarians living a terrestrial life are tropical forms, only 7 of the 348 species now known to science being found in the palæartic (European subregion) and nearctic regions. Of these a single species, excluding *Platocephalus kewensis* an introduced form occurring in hot houses, has been described from the United States. This species, *Rhynchodemus sylvaticus*, was established by Leidy in 1851 based on five specimens collected in Philadelphia.

The occurrence of a species of *Rhynchodemus* at Gambier, Ohio, differing in many particulars from the form to which Leidy called attention is in consequence of considerable interest. Five representatives of this species were found on the partially decayed stem of a virginia creeper July 9, 1904, near Bexley Hall. A somewhat more extended study and a comparison, if possible, with the type of *R. sylvaticus* will undoubtedly show the relationship between the two forms.

¹Read before the Ohio State Academy of Science, Nov. 26, 1904.

ACTINOLOPHUS MINUTUS, A NEW HELIOZOAN,
WITH A REVIEW OF THE SPECIES
ENUMERATED IN THE GENUS^{1*}

While examining late in October some sediment in a jar containing *Hydra fusca* collected September 17, 1904, in the Kokosing River, attention was attracted by a small stalked form of heliozoan-like appearance. This, a single example of which was observed, on more careful study proved referable to the genus *Actinolophus* (Heliozoa) the representatives of which are not met with frequently, none to the knowledge of the present writer having thus far been noted in America.

Although there is considerable uncertainty as to the exact relation of the species constituting the group to the other Protozoa, the characteristics of the form in question appear to merit record, differing as it does from *A. capitatus* Penard through the absence of knobbed pseudopodia as well as in its much smaller size, and from *A. pedatus* (Zach.) by the spherical form of the body which is ovoid in the latter and much larger than the body of *A. minutus*.

Schulze, 1874, formed the genus *Actinolophus* for the reception of *A. pedunculatus* a marine form from the Baltic Sea described by him. Penard, 1890, described *A. capitatus* from a single individual suggesting its close relationship with the tentacliferous infusoria (Suctoria). Zacharias, 1893, in a brief description, called attention to a new Heliozoan, *Actinosphaeridium pedatus* which Schaudinn, 1896, in his monograph of the Heliozoa, placed provisionally in the genus *Actinolophus*, recognizing for that genus three species, two of which were of doubtful value. Penard, 1904, in his valuable monograph of the fresh water Heliozoa, mentions both *A. capitatus*

¹Read before the Ohio State Academy of Science Nov. 26, 1904.

*Reprinted from *The Ohio Naturalist*, vol. 5 (1905), pp. 261-263.

and *A. pedatus* among forms whose position is doubtful, suggesting possible affinities with *Tokophrya* and *Nuclearia*, noting at the same time the desirability for further study. Until a better knowledge is obtained of their affinities, however, it seems advisable to consider them under the genus *Actinolophus*.

The following summarizes our present knowledge of the group and indicates the position of *A. minutus* in respect to the other species.

Genus ACTINOLOPHUS, Schulze

1874 *Actinolophus*, F. E. Schulze, Arch. mikr. Anat. v. 10, p. 392. (?) 1893 *Actinosphaeridium*, O. Zacharias, Forschungber Plon., v. 1, p. 15. 1896 *Actinolophus*, Schaudinn, Das Tierreich, Heliozoa, Berlin.

Body spherical or oval, provided with a pedicle the length of which is usually much greater than the diameter of the body. Body generally (always?) provided with a gelatinous envelope through which the fine pseudopodia are extended. Nucleus excentric contractile vacuole (?).

The following table will serve to separate the forms:

A¹ Pseudopodia not knobbed at the extremity.

B¹ Pedicle 3-4 μ in diameter, marine forms,

A. pedunculatus

B² Pedicle not more than 2 μ in diameter, fresh water forms,

C¹ Body ovoid, diameter 18 μ , length 23 μ ,

A. pedatus

C² Body spherical, diameter 12 μ , *A. minutus*

A² Pseudopodia knobbed at extremity, diameter 30 μ , fresh water forms,

A. capitatus

1. A. PEDUNCULATUS, Schulze, 1874 A. p. F. E. Schulze, Arch. mikr. Anat., v. 10, p. 392, f. 1-9. 1896 Schaudinn, Das Tierreich, Heliozoa, Berlin, p. 11.

Length of body, up to 30 μ , length of pedicle up to 100 μ , diameter of pedicle 3-4 μ .

Marine, Baltic Sea.

2. A. PEDATUS, (Zach.) 1893 *Actinosphaeridium pedatum*, Zacharias, Forschungber. Biol. Stat. Plon., v. 1, p. 15, f. 9a, 9b. 1896 ? *Actinolophus pedatus*, Schaudinn, Das Tierreich, Heliozoa, Berlin, p. 11. 1904 ? *Actinosphaeridium pedatum*, (? *Nuclearia caulescens*), (? *Tokophrya*), Penard, Les Heliozoaires d'eau douce, p. 318.

Length of body 23μ , diameter 18μ , length of pedicle $11-30\mu$, diameter 1.7μ . Body provided with a thick gelatinous envelope from which extends extremely fine and rather short pseudopodia. Nucleus oval, situated in the inferior part of the body. Contractile vesicle not known. Color pale yellow, individuals occasionally agglomerated by their bodies into colonies.

Fresh water, Germany.

Zacharias placed *A. pedatus* in a new genus *Actinosphæridium* on the basis that it differed from *Actinolophus* by possessing, in the encysted condition, plates covering the body. Schaudinn enumerates it among the doubtful species of *Actinolophus*, while Penard refers it back to *Actinosphæridium*, at the same time calling attention to its remarkable similarity to *Nuclearia* and to *Tokophrya*.

3. *A. MINUTUS*, n. sp.

Body spherical, diameter 12μ including gelatinous envelope approximately 1μ thick. Length of pedicle 70μ , diameter 1μ . Extremely fine short pseudopodia of about 2μ in length extend beyond the envelope on all sides. Nucleus suboval situated in the inferior part of the body. Contractile vesicle (?). Base of pedicle (in the form studied) imbedded in a gelatinous mass $10-12\mu$ in extent containing small algæ, etc.

Gambier, Ohio, U. S. A.

A single specimen observed Oct. 29, 1904, in sediment from an aquarium jar containing *Hydra fusca*, the entire contents of the jar having been collected Sept. 13, 1904, in the Kokosing River at Gambier and subsequently covered with a glass plate for the purpose of preventing too rapid evaporation. The form was under observation at intervals during a period of four hours.

4. *A. CAPITATUS*, Penard. 1890 A. c. Penard, *Jahrb. nassau. Ver.*, v. 43, p. 16 t. 1 f. 11. 1896 A. c. Schaudinn, *Das Tierreich*, Heliozoa, Berlin, p. 12. 1901 A. p. Sand, *Etude monographique sur le groupe des Infusores tentaculifères*, Ann. Soc. Belge de Microscopie. 1904 A. c. Penard, *Les Heliozoaires d'eau douce*, Geneva, p. 316.

Diameter 30μ , length of pedicle 90μ . Nucleus (?), Contractile vesicle, Pseudopodia few in number, knobbed.

In fresh water, Germany.

Penard described this species in 1890 from a single individual referring it to the genus *Actinolophus* although noting its close relationship with the tentaculiferous infusoria. Sand, 1901, in his study of that group came to the conclusion that *A. capitatus* was nearer related to the Heliozoa than to the Suctoria for the following reasons, (a) the pedicle resembles that of *Clathrulina elegans*, (b) the pedicle does not penetrate into the gelatinous envelope as in *Tokophrya limbata* one of the Suctoria, (c) the nucleus is excentric, (d) the species closely resembles *A. pedunculatus*. Penard, 1904, in his paper on the fresh water Heliozoa, after having examined several more specimens which he remarks are exceedingly rare, insisted on the suctorian nature of the form, maintaining that the points raised by Sand have little value. Penard at the same time suggests the desirability for a further study of the form. Consequently it seems advisable at present to allow it to remain in the genus *Actinolophus*.

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NAIDIDÆ OF CEDAR POINT, OHIO*

The microscopic annelids constituting the family Naididæ of the subclass Oligochæta are a group which has received little attention in America. Michaelsen (:00) in his monograph of the Oligochæta recognized 42 species from various parts of the world and of that number only 6 were noted as occurring in our territory although observations made by Smith (:00) and noted in the appendix ("Zusätze und Berichtigungen") increased the number to 12. While this, taken in connection with the fact that the observations have been confined almost entirely to two localities, the one in Pennsylvania the other in Illinois, furnishes sufficient justification for a review of the Naididæ occurring at Cedar Point, Ohio, some contemplated studies of a statistical nature rendered a preliminary survey of several groups of fresh water organisms desirable for the purpose of ascertaining which could be used most advantageously in the problems under consideration. Consequently the present paper is purely from a systematic standpoint, and although a considerable number of specimens have been fixed, stained, and mounted, and a few imbedded and sectioned, no attention beyond that necessary to differentiate the species has been given to anatomical or histological structure.

In addition to the interest attached to the study of these organisms upon the side of pure science, as outlined above, the fact that they play a rôle of decided economic importance must not be overlooked. The relation of the microscopic organisms or "plankton," accepting the definition in its broadest sense, to the distribution of food fishes is a subject which has received increasing attention during the past twenty years. Inasmuch as the food of fishes is made up chiefly of small Crustacea, insect larvæ, minnows, etc., the existence of these being in turn depend-

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ent on microscopic forms, among which the Naids occupy an important position, it is evident that the distribution of such microscopic organisms controls to a large extent the fish supply in any given locality.

The somewhat unique location of Cedar Point with the open lake on the north and a portion of Sandusky Bay extremely rich in aquatic vegetation on the south, renders the Lake Laboratory situated there a station particularly well adapted to the study of the animal and plant life occurring in fresh water and to the investigation of the various problems of biological importance connected therewith.

The present study was carried on at the laboratory during a period of six weeks in July and August, 1905, the greater portion of the time, however, being occupied with other work. Consequently the record of species is undoubtedly far from complete, although 10 species, 7 of them new to science, are noted. The large proportion of new forms indicates the present condition in regard to the systematic study of the Naids in the United States, and while the writer has no wish to be classed as a "species maker," nevertheless it is important to lay the foundations for future biological studies by first considering those groups containing individuals resembling each other sufficiently well to be called "species."

The principal papers dealing with American Naids outside of the excellent monographs of Michaelsen (:00) and Beddard ('95), are those of Leidy ('50a, '50b, '52a, '52b, '80), Minor ('63), Reighard ('85), Cragin ('87), and Smith ('96 and :00). In addition to these, papers indispensable to the student of the group have been published by Beddard, Benham, Bourne, Bousfield, Bretschner, Michaelsen, Tauber, and Vejdovsky, that of the last author being classical in its morphological treatment of the forms. The majority of these papers are either in the library of the writer, or in the library of the department of biology of Kenyon College. Mention should here be made of the courtesies extended by the American Museum of Natural History, New York, the library of Cornell University, and the Museum of Comparative Zoölogy of

Harvard University, in the loan of literature otherwise inaccessible. I am furthermore greatly indebted to Samuel Henshaw of the Museum of Comparative Zoölogy for noting certain references.

The studies of the various species were made primarily from living specimens, all figures having been drawn with the aid of the camera lucida at the magnification noted in each instance. The most satisfactory method was that of transferring the Naid from the culture by means of a pipette to a watch-glass and subsequently to a drop of water on a slide, then placing over the drop a cover-glass the margin of which was supported by an extremely thin wooden wedge. After a time the specimens, without undue compression, would become quiet and outline drawings could be made with the camera. Specimens to be mounted were fixed with hot sublimate-alcohol (sublimate 10 g., absolute alcohol 100 cc., distilled water 100 cc., acetic acid 2 cc.), stained in borax-carmines, and eventually transferred to balsam, while those sectioned were stained in hæmatin IA (Apathy) or in iron-hæmatoxylin (Heidenhain) after fixation in cold sublimate-alcohol. The index of refraction of balsam approaches so closely the refraction of the transparent setæ that in order to study them most advantageously it was found advisable to kill the specimens by compressing them under the cover-glass and then at once to make camera lucida drawings of the setæ in the dorsal and ventral bundles.

The Naididæ are distinguished from the other families of the Oligochæta primarily by the fact that their normal method of reproduction is by means of budding, and that complete intersegmental dissepiments are present. The closely allied family Æolosomatidæ are without dissepiments and are usually of much smaller size. Furthermore, the presence of colored "oil drops" together with the absence of biuncinate setæ are characters which as a rule¹ will serve to distinguish these families. The Enchytræidæ may be separated by the absence of biuncinate setæ,

¹Colored oil drops are absent in *Æolosoma beddardi*, *Æolosoma niveum* from North America, and two species of *Pleurophleps* occurring in Ceylon and Central America.

while representatives of the families Lumbriculidæ and Tubificidæ usually exceed 20 mm. in length, while the Naididæ on the contrary are rarely more and usually much less than 15 mm. in length.

The form and position of the setæ are the chief characters relied upon for the separation of the genera and species. These may be long and hair-like (capilliform), short and straight (needle-like), or S-shaped (sigmoid), and may terminate simply or in two hooks (biuncinate). A slight enlargement (nodulus) is usually present on all biuncinate setæ. The accompanying diagrams representing a typical Naid together with the different forms of setæ will prove of assistance in making clear the characters used in the synoptic table which has been slightly modified from Michaelsen (:00) who in turn adopted a large proportion of it from Vejdovsky ('84). The reproductive organs have not been sufficiently studied to admit of a final conclusion concerning their typical arrangement. This includes all genera known up to the present time, those occurring in North America being printed in heavier type. Since the publication of this monograph by Michaelsen one new genus (Hæmonais) has been founded by Bretscher, while Michaelsen (:03) has proposed the name Vejdovskyella for Bohemilla, the latter being pre-occupied.

FAMILY NAIDIDÆ

- 1791. *Nais* [ex Ord. Mollusca, e Class. Vermes] (part) Gmelin, *Syst. Nat.*, vol. 6, p. 3120.
- 1895. *Naidomorpha* (e Group *Microdrili*) Beddard, *Monogr. Olig.*, p. 275.
- 1900. *Naididæ* Michaelsen, *Monogr. Olig.*, *Das Tierreich*, Lief. 10, p. 16.
- 1903. *Naididæ* Michaelsen, *Die geogr. Verbreit. d. Olig.*, p. 41.
- 1905. *Naididæ* Michaelsen, "Zur Kenntnis d. Naididen," *Zoologica*, vol. 18, p. 350.

Setæ aggregated together in 2 or 4 bundles on a segment. Dorsal bundles composed of capilliform, short needle-like, or sigmoid (the latter biuncinate) setæ; dorsal bundles often absent; ventral bundles composed of sigmoid biuncinate setæ. Dissepiments well developed. Brain, commissure, and ventral nerve-cord well developed, distinct from the hypodermis. Esophagus without muscular stomach. Nephridia large, occasionally entirely absent.

Testes in segment 5 or 7 (rarely in segments 8 and 9). Ovaries in segments 6 and 7 (rarely in segment 10). Spermatheca in segment 5 or 7. Reproduction normally asexual by budding. Length of specimens varies from 1 to 50 mm.; usually from 2 to 10 mm.

Usually in fresh water, rarely in saline waters. One (*Amphichæta*) marine. Cosmopolitan; fifteen genera.

Synoptic Table for Separation of Described Genera

(Genera occurring in North America printed in capitals)

- A¹. Capilliform setæ absent.
 - B¹. Dorsal bundles of setæ absent.
 - C¹. Ventral bundles of setæ on all segments beginning with the second. Third segment not longer than remaining segments
Schmardella.
 - C². Ventral bundles of setæ absent on segment 3-5. Segment 3 extremely long CHÆTOGASTER.
 - B². 2 dorsal and 2 ventral bundles of setæ on a segment.
 - C¹. Segment 3 much longer than remaining segments. Length (of described species) not exceeding 2 mm. . . *Amphichæta*.
 - C². Segment 3 not longer than remaining segments. Length (of described species) equal to or exceeding 5 mm.
 - D¹. All setæ of dorsal bundle biuncinate *Paranais*.
 - D². Some of the setæ of dorsal bundle not biuncinate
OPHIDONAIS.
- A². Capilliform setæ present in the dorsal bundle.
 - B¹. Dorsal bundle of setæ beginning on segment 2, 5, or 6.
 - C¹. Dorsal bundle of setæ beginning on segment 5 or 6.
 - D¹. Posterior end developed into a tubular respiratory process containing paired gills. Usually living in tubes composed of plant fragments, etc. DERO.
 - D². Posterior end without respiratory processes.
 - E¹. Capilliform setæ of dorsal bundle with a series of prominent teeth. Dorsal bundle beginning on segment 5
Vejdovskyella.¹
 - E². Capilliform setæ without teeth. Dorsal bundle beginning on segment 6.
 - F¹. Length of capilliform setæ equal to at least twice the diameter of the body.
 - G¹. Capilliform setæ on all segments beginning with 6. Prostomium rounded *Macrochætina*.

¹For *Bohemilla*, previously used as the generic name for a group of Trilobites by Barrande, (Michaelsen, :03).

- G². Capilliform setæ only on one (6) or a few (6, 7, 8) segments.
- H¹. Capilliform setæ on segments 6, 7, and 8. Prostomium developed into a tentacular process
Ripistes.
- H². Capilliform setæ only on segment 6. Prostomium not developed into a tentacular process
SLAVINA.
- F². Length of capilliform setæ shorter or rarely longer than diameter of body.
- G¹. Prostomium developed into a tentacular process
STYLARIA.
- G². Prostomium rounded NAIS.
- C². Dorsal bundle of setæ beginning on segment 2.
- D¹. Anterior capilliform setæ partly covered by filamentous gills *Branchiodrilus*.
- D². No filamentous gills present.
- E¹. Dorsal bundle usually composed entirely of capilliform setæ. Prostomium developed into a long tentacular process PRISTINA.
- E². Dorsal bundle composed in part of biuncinate or of short needle-like setæ. Prostomium rounded or with a short tentacular process NAIDIUM.
- B². Dorsal bundle of setæ beginning on segment 12-20 *Hæmonais*.

Genus CHÆTOGASTER K. Baer, 1827

Prostomium rudimentary, coalesced with segment 1; 2 ventral bundles of setæ on a segment, these absent on segments 1 and 3-5. Setæ uncinatæ. Pharynx large and wide. Esophagus small, not longer than pharynx; 1 pair of transverse vessels connects the dorsal and the ventral vessels. Longitudinal commissures of ventral nerve-cord more or less distinct in anterior part of body. Testes in segment 5, ovaries in segment 6, spermathecæ in segment 5.

In fresh water, free-living or parasitic on fresh-water snails. Middle and south Europe, North America.

Five species are recognized by Michaelsen and to these must be added *C. pellucidus*. Three species of *Chætogaster* (*C. diastrophus*, *C. diaphanus*, and *C. limnæi*) have been reported from North America, while Leidy ('52), described *C. gulosus*, so incompletely, however, that it can-

not be recognized, although undoubtedly referable to the genus *Chætogaster*.

The following table will serve to separate all the species known at the present time:—

- A¹. Prostomium distinct, usually with a pore on anterior margin
C. diastrophus.
(Europe, N. America.)
- A². Prostomium indistinct.
 - B¹. Length of individuals not exceeding 5 mm.
 - C¹. Esophagus as long as pharynx.
 - D¹. Blood vessels of pharyngeal region well developed *C. langi*.
(Europe, N. America.)
 - D². Blood vessels of pharyngeal region absent or only slightly developed *C. crystallinus*.
(Europe.)
 - C². Esophagus shorter than pharynx, indistinct.
 - D¹. Ventral setæ 8 to 12 in bundle, 1st postesophageal dilation of intestine covered with anastomosing network of blood vessels *C. limnæi*.
(Europe, N. America.)
 - D². Ventral setæ 6-7 in bundle, 1st postesophageal dilation of intestine surrounded by 12 or more pairs of non-anastomosing transverse blood vessels *C. pellucidus*.
(N. America.)
 - B². Length of individuals 10-15 mm. *C. diaphanus*.

CHÆTOGASTER LANGI Bretscher

C. langi Bretscher, *Rev. Suisse Zool.*, vol. 3, p. 512, fig. 1, 1896;
 Michaelsen, *Das Tierreich, Oligochaeta*, Berlin, p. 21, 1900.

Living specimens transparent. Prostomium blunt, indistinct. Setæ unequally bifid at distal end, 4 in a bundle. Esophagus long. Ventral ganglia glandular in form. Circulatory system with normal development in the pharyngeal region, 1 pair of transverse vessels (not developed as "hearts") in esophageal segment. Length 1-2 mm.

Between filaments of algæ in swampy places, etc.

One specimen referable to this species was obtained early in July. There were several minor characteristics not wholly in agreement with the description of *C. langi*,

but in the absence of more material it must be placed here.

CHÆTOGASTER PELLUCIDUS n. sp.

Transparent. Prostomium indistinct. Eyes absent. Dorsal setæ absent, ventral setæ 6-7 in a bundle, biuncinate, with teeth unequal. Esophagus short, postesophageal dilation first stomach) surrounded by 12 or more pairs of non-anastomosing transverse blood vessels. Length 1.5 mm. Number of segments in an individual from 9 to 11. Budding in all specimens observed.

Sandusky Bay, Lake Erie.

A considerable number of specimens of this small Chætogaster were observed in cultures of aquatic plants during July and August, and a number were stained and mounted and are now in the collection of the Museum at Kenyon College. All found were free living, while *C. limnæi*, to which it is most closely allied, normally occurs on or in fresh-water snails. It is possible, however, that they may have left their host as the age of the culture increased. No snails were observed in the jar.

Furthermore, Vejdovsky ('84) figures the first postesophageal dilation of *C. limnæi* as being covered with an anastomosing network of blood vessels, while in *C. pellucidus* they are plainly non-anastomosing.

Genus DERO Oken, 1815

Prostomium rounded, eyes absent. Setæ in four bundles on a segment. Ventral setæ uncinatæ, those of the segments 2 to 5 longer than the rest; dorsal bundle usually beginning on the 6th rarely on the 5th segment, composed of a capilliform and one or two needle-like setæ with variously formed distal ends. Posterior end developed into branchial filaments. Intestine with stomach. Blood red. Nephridia paired from 6th segment. Testes in 5th, ovaries in 6th, spermathecæ in 5th segments.

Fresh water. Europe, North America, Antilles, tropical East Africa, Tonkin, Philippines; fifteen species.

Four species of Dero have been reported from North America: *D. obtusa*, *D. limosa*, *D. vaga*, and *D. furcata*.

DERO VAGA (Leidy)

Anulophorus vagus Leidy, *Amer. Nat.*, vol. 14, p. 423, figs. 3, 4, 1880; Reighard, *Proc. Amer. Acad.*, vol. 20, p. 88, pl. 1, figs. 1-10; pl. 2, figs. 11-20; pl. 3, figs. 21-31, 1885.

Dero vaga L. Vaillant, *Hist. Nat. Annel.*, vol. 3, p. 383, 1890; Stieren, *Sitzb. Ges. Dorpat*, vol. 10, p. 107, 1893.

D. furcata Bousfield (part), *Journ. Linn. Soc. London*, vol. 20, p. 105, 1887.

D. vaga Michaelsen, *Das Tierreich, Oligochaeta*, p. 29, 1900.

Prostomium rounded. Ventral bundle of segments 2 to 5 with 8 to 14 long slightly curved, biuncinate setæ, with upper somewhat longer than the lower tooth. Ventral bundles of remaining segments with 4 to 7 shorter, more curved, biuncinate setæ with the upper shorter than the lower tooth. Dorsal bundle of setæ beginning on 6th segment; composed of 1 to 3 capilliform and 1 to 3 palmate setæ.

Posterior end with rudimentary branchia and two long finger-like processes. Three pairs of hearts in segments 8, 9, and 10. Brain wider than long. Length 8 mm. or more; number of segments in an individual 24 to 35.

In slime of ditches, etc., among fresh-water plants. Massachusetts (Cambridge), Pennsylvania (Philadelphia), Illinois, Ohio (Cedar Point), and Trinidad, West Indies.

This species was extremely common at Cedar Point, particularly among cultures containing *Riccia fluitans*, the thallus of which together with statoblasts of Bryozoa, etc., it uses in the building of a protective tube by means of a viscid secretion from the body. When walking around with its tube it bears a striking resemblance to a minute caddis-fly larva.

Genus STYLARIA Lamarck, 1816

Prostomium developed into a tentacular process. Ventral bundles composed of biuncinate setæ; dorsal bundle composed of capilliform setæ, beginning on 6th segment. Testes in 5th, ovaries in 6th, spermatheca in 5th segment.

Fresh water. Europe, North America; one species.

STYLARIA LACUSTRIS (Linné)

Nereis lacustris Linné, *Syst. Nat.*, ed. 10, p. 654, 1758; ed. 12, vol. 2, p. 1085, 1767.

Stylaria lacustris Johnston, *Cat. Brit. Non-paras. Worms*, p. 70, 1865; Vejdovsky, *Syst. Morphol. Olig.*, p. 30, pl. 3, fig. 27; pl. 4, figs. 1-24, 26-31, 1884.

Nais lacustris Beddard, *Monogr. Olig.*, p. 284, 1895; Michaelsen, *Das Tierreich, Oligochaeta*, p. 33, 1900.

S. paludosa, *S. fossularis* Leidy, *Proc. Acad. Nat. Sci. Phila.*, vol. 5, pp. 286, 287, 1852.

S. philadelphiana, *S. scotica* Czerniavsky, *Bull. Soc. Imp. Nat. Moscou*, vol. 55, no. 4, p. 309, 1880.

Prostomium developed into a long tentacular process. Eyes usually present. Distal teeth of ventral setæ unequal. Dorsal setæ capilliform with 1 long and 1 to 2 short in each bundle. All long setæ of each bundle approximately of the same length. Clitellum in sexually mature forms on segment 6. Male pores on 6th segment. Sperm duct in 5th, spermatheca in 5th segment. Length 10 to 15 mm. Number of segments about 25.

Europe, North America (Pennsylvania, Ohio, Illinois).

A large number of specimens were observed which must at present be referred to this species. Michaelsen notes the length of *N. lacustris* as varying between 10 and 15 mm., while the length of those found at Cedar Point was always from 4 to 5 mm. The teeth of the ventral setæ are also considerably shorter and more obtuse than illustrated in the figures of Vedjovsky ('84), Tauber, and others. Furthermore, the length of the tentacular process in those forms observed, did not exceed the length of the long capilliform setæ while Müller (1774) notes the length of the tentacular process as equivalent to ten segments of the body. The synonymy of *S. lacustris* is in a confused condition, and it is possible that careful study will establish one or more new species in the genus.

The imperfect descriptions given by Leidy ('52b) to the species described by him as *S. paludosa* and *S. fossularis*, will not permit their separation from *S. lacustris*.

Genus NAIS Müller, 1774

Prostomium rounded. Ventral bundle with biuncinate setæ. Dorsal bundle beginning on the 6th segment with capilliform and variously pointed short setæ. Testes in 5th, ovaries in 6th, spermatheca in 5th segments (in species where sex organs have been observed).

In fresh water. Europe, North America, South America, and East India; ten species.

The genus *Nais* furnishes one of the most difficult problems for the systematist attempting to define the limits of species among the Naididæ. The following table, however, embodies the results of systematic work so far as they are known and comprises all species described up to the present time.

A¹. Setæ of ventral bundle of segments 8 to 10 neither thicker than those of other segments nor modified by possessing blunt tips with rudimentary lower tooth.

B¹. Eyes present.

C¹. Ventral setæ of segments 2 to 5 much longer than those of succeeding segments. Dorsal setæ capilliform, 4 to 8 in bundle *N. obtusa*.
(Europe, S. Siberia.)

C². Ventral setæ of segments 2 to 5 not decidedly longer than those of succeeding segments.

D¹. Transverse blood vessels simple.

E¹. Ventral setæ of segments 2 to 5 unequally bifid at tip. Length 1 to 1.5 mm. *N. elinguis*.
(Europe, N. America, S. America.)

E². Ventral setæ of segments 2 to 5 equally bifid at tip.

F¹. Number of segments in an individual approximately 10 (9 to 10), 6 to 8 ventral setæ in a bundle. Length of specimen 1.5 mm. *N. parvula*.
(N. America.)

F². Number of segments in an individual usually 20 (18 to 22), 4 ventral setæ in a bundle. Length of specimens at least 2 mm.

G¹. Dorsal bundles composed of 1 long capilliform and 2 short needle-like setæ. Eyes dumbbell-like in form *N. tortuosa*.
(N. America.)

G². Dorsal bundle composed of 1 long capilliform and 1 short biuncinate seta. Eyes oval, not dumbbell-like in form. Length 3.5 mm. *N. parviseta*.
(N. America.)

D². Transverse blood vessels of segments 2 to 5 forked. Dorsal bundle with biuncinate setæ. . . . *N. heterochæta*.
(England.)

B². Eyes absent.

C¹. Proximal tooth of dorsal biuncinate setæ not longer than the distal tooth.

D¹. Ventral bundle composed of 3 to 4 setæ. Length of individuals 3 to 3.5 mm. Colorless *N. tenuidentis*.

- D². Ventral bundle composed of 6 to 8 setæ. Length 6 to 8 mm. Color reddish *N. josinae*.
(Europe, N. America.)
- C². Proximal tooth of dorsal biuncinate setæ twice the length and twice the thickness of the distal tooth *N. paraguayensis*.
(S. America.)
- A². Setæ of ventral bundle of segments 8 to 10 much thicker than those of other segments, 1 to 2 in number, tips blunt, proximal tooth rudimentary *N. bretscheri*.
(Europe.)

NAIS PARVULA n. sp.

Prostomium blunt, rounded. Eyes present. Digestive tract not differentiated into esophagus and stomach. Dorsal bundle beginning on segment 6, composed of 1 capilliform, subequal to diameter of body, and 2 short biuncinate setæ. Ventral bundle consisting of 6 to 7 biuncinate setæ with teeth equal. Length 1.2 mm. Number of segments in an individual 9 to 10.

Cedar Point, Sandusky, Ohio.

Several examples of this extremely small Nais were found in the slime accumulating at the bottom of jars containing roots of various aquatic plants obtained from Sandusky Bay. It is chiefly remarkable by reason of its small size, and the limited number of segments composing the body. At first it seemed probable that it was an immature form but evidence to the contrary was given by budding in several specimens.

NAIS TORTUOSA n. sp.

Prostomium blunt, rounded. Eyes present slightly dumbbell-shaped. Digestive tract not differentiated into esophagus nor stomach. Dorsal bundle beginning on 6th segment, composed of 1 long capilliform (180 μ) and 2 short (50 μ) needle-like setæ. Ventral bundle consisting of 4 biuncinate setæ (110 μ) with subequal teeth. Length 2.2 mm. Number of segments in an individual 18.

Cedar Point, Sandusky, Ohio.

Two specimens belonging to this species were noted. Budding was not observed. Several Peritrichous ciliates (*Rhabdostyla* sp., length 50 μ , diameter 19 μ) were ob-

served fixed to the anterior end of one of the individuals, the peduncle being less than 2μ in length.

NAIS PARVISETA n. sp.

Prostomium narrow, slightly acute. Eyes present, round or slightly oval. Digestive tract differentiated into a distinct pharynx which gradually merges into an esophagus. Stomach dilation scarcely perceptible. Dorsal bundle beginning on the 6th segment, composed of 1 capilliform, subequal to diameter of body, and 1 short biuncinate seta, possessing equally developed teeth and an indistinct nodulus. Ventral bundle composed of 3 to 4 biuncinate setæ, with lower tooth considerably larger than the upper tooth. Length 3.5 mm. Number of segments in an individual 19 to 20.

Cedar Point, Sandusky, Ohio.

A very few specimens of this form were observed. Budding was noted in nearly all of the individuals examined. The characteristic differentiation of the teeth on the ventral setæ appears to be of considerable specific importance.

NAIS TENUIDENTIS n. sp.

Prostomium blunt. Eyes absent. Digestive tract not differentiated into esophagus or stomach, covered with many brownish globules. Dorsal bundle beginning on 6th segment, composed of 1 capilliform, the length (180μ) of which is approximately one half the diameter of the body, and 1 short (60μ) biuncinate seta possessing equally developed teeth and provided with a nodulus. Ventral bundle consisting of 4 (3 in several anterior bundles) deeply bifid setæ, both teeth being exceedingly long and slender, the upper measuring 20μ and the lower 14μ from the base of the cleft area. Length 3 to 3.5 mm. Number of segments in an individual approximately 20. Budding observed.

Cedar Point, Sandusky, Ohio.

Only two specimens of *N. tenuidentis* were found, budding occurring in each. The extremely long and

slender teeth of the ventral setæ are a striking characteristic of this species.

Genus PRISTINA Ehrenberg, 1831

Prostomium usually developed into a tentacular process. Ventral bundle composed of biuncinate setæ. Dorsal bundle beginning on the 2nd segment, composed of capilliform setæ. Testes in 7th, ovaries in 8th, spermatheca in 7th segments (description of sexual organs based on observation of one species, *P. leidyi*).

In fresh water. Europe, North America, South America, and Java; 6 species.

The species may be separated by the following table. While it is possible that a careful study of *P. æquiseta*, *P. longiseta*, and *P. flagellum*, may show that those responsible for the descriptions have overlooked the existence of the small teeth present in *P. leidyi* and *P. serpentina*, it appears evident that the species are distinct on other grounds.

A¹. Setæ of dorsal bundle smooth.

B¹. Last segment not provided with finger-like processes.

C¹. Dorsal setæ of 3d segment not decidedly longer than those of other segments; length 7 to 8 mm. *P. æquiseta*.
(Europe.)

C². Dorsal setæ of 3d segment much longer than those of other segments *P. longiseta*.
(Europe.)

B². Last segment provided with 3 (2 lateral and 1 median) finger-like processes projecting posteriorly *P. flagellum*.
(N. America, S. America.)

A². Setæ of dorsal bundle provided with numerous fine but distinct teeth.

B¹. Capilliform setæ of dorsal bundle approximately 35 μ long. Those of the 3d segment twice as long as the others *P. leidyi*.
(N. America, S. America.)

B². Capilliform setæ of dorsal bundle approximately 300 μ long. Those of the 3d segment not longer than others.

C¹. Teeth of ventral setæ subequal. Number of segments approximately 14 *P. serpentina*.
(N. America.)

C². Distal teeth of ventral setæ longer than proximal teeth. Number of segments 18 to 30 *P. proboscidea*.
(S. America.)

PRISTINA SERPENTINA n. sp.

Prostomium developed into a long tentacular process, usually 0.2 to 0.3 mm. in length. Eyes absent. Digestive tract with stomach in the anterior part of the 8th segment. Dorsal bundle beginning on the 6th segment, composed of 2 long (300μ), 1 medium (100μ) capilliform setæ, and 2 to 6 short needle-like (30μ to 50μ) setæ. Ventral bundle composed of 5 to 6 biuncinate (60μ to 80μ) setæ with subequal teeth. Length 2.2 mm. Number of segments in an individual about 15.

Cedar Point, Sandusky, Ohio.

This species of *Pristina* was exceedingly abundant at Cedar Point, and on first examination was apparently to be placed near *P. æquiseta* Bourne. Closer examination, however, demonstrated the existence of fine teeth on the setæ of the dorsal bundle. The difference in the form of the distal teeth of the ventral setæ distinguishes it from *P. proboscidea* Beddard, now recognized by Michaelsen (:05) as a valid species.

Genus NAIDIUM O. Schmidt, 1847

Prostomium either rounded, pointed, or developed into a short tentacular process. Dorsal bundle beginning on the 2d segment, composed of capilliform, or needle-like, and biuncinate setæ. Ventral bundle composed of biuncinate setæ.

Fresh water. Middle Europe, East India, North America, and South America; six species.

A¹. Prostomium not developed into a tentacular process.

B¹. Number of segments composing an individual usually 15 to 30 (32 to 40, *N. luteum*). Biuncinate setæ in dorsal bundle.

C¹. Prostomium rounded or pointed, species small, not exceeding 5 mm. in length.

D¹. Number of segments in an individual 20, posterior part of brain developed into 4 pronounced lobes *N. bilobatum*.
(Europe.)

D². Number of segments in an individual 15 to 16.

E¹. Capilliform setæ shorter than the diameter of the body. Teeth of dorsal biuncinate setæ approximate *N. uniseta*.
(Europe.)

- E². Capilliform setæ longer than the diameter of the body.
Teeth of dorsal biuncinate setæ remote . . . *N. osborni*.
(N. America.)
- C². Prostomium slightly elongate, species large, approximately
15 mm. in length *N. luteum*.
(Europe.)
- B². Number of segments in an individual 40 to 61, no biuncinate
setæ in dorsal bundle *N. dadayi*.
(S. America.)
- A². Prostomium developed into a short tentacular process, length of
species approximating 8 mm. *N. breviseta*.
(East India.)

NAIDIUM OSBORNI n. sp.

Prostomium moderately long, somewhat pointed. Eyes absent. Digestive system differentiated into pharynx (segments 1 to 3), esophagus (segments 4 to 7), and stomach (8th segment). Dorsal bundle of setæ beginning on the 2d segment, composed of 1 long capilliform (145μ) and 1 short (50μ) seta, the latter biuncinate with subequal, remote teeth and an indistinct nodulus one third the distance from the tip. Ventral bundle composed of 4 biuncinate setæ with subequal teeth and a distinct nodulus midway between base and tip. Length 1.6 mm. Number of segments in an individual 15 to 16. Budding observed.

Cedar Point, Sandusky, Ohio.

Five species of *Naidium* have been described; three from central Europe, one from the East Indies, and one from South America; none, however, has been noted in North America, consequently the occurrence of a distinct species in the United States is of considerable interest. A single individual was found in the sediment of a bottle containing "reed roots" obtained at Cedar Point, Ohio, and received from Professor Osborn, September 4, 1905.

Schmidt (1847) founded the genus upon a single species, *N. luteum*, occurring in Europe. Beddard ('95) maintained that this species should be incorporated in the genus *Pristina* inasmuch as *Pristina breviseta* described by Bourne (1891) nearly bridged over the gap formerly supposed to separate the two genera. Michaelsen (:00)

removed *P. breviseta* to the genus *Naidium* which thus consisted of two species, *N. luteum* and *N. breviseta*.

The characters which may be used for separating the two genera consist of (1) the presence as a rule of biuncinate setæ in the dorsal bundle of *Naidium*, while such setæ are absent in *Pristina*, and (2) the development of the tentacular process of the prostomium which is either absent or extremely short in *Naidium* while in *Pristina* it is long. The absence of any tentacular process in *N. osborni* suggests that until a species is found in which the process is well developed and in which the dorsal bundles contain biuncinate setæ, the genera may be considered distinct. Further studies may show other generic characters.

I take pleasure in dedicating this species to Professor Herbert Osborn, Director of the Lake Laboratory, Sandusky, Ohio.

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THE RELATION OF VARIABILITY TO FOOD
SUPPLY AS ILLUSTRATED BY THE WHITE
DAISY, *CHRYSANTHEMUM LEUCANTH-*
EMUM L. AND THE YELLOW PERCH,
PERCA FLAVESCENS MITCH.*

Notwithstanding the numerous biological problems which have been attacked by means of statistical methods during the last ten years, an absence of evidence concerning the effect of food supply upon the variability of organisms exists. It was with a view toward obtaining data bearing upon this particular problem that the present investigation was undertaken. While the natural environment by no means furnishes conditions for obtaining the best results, it seemed advisable, at least in a preliminary survey of the subject, to adopt such a method.

In the first part of the investigation results were obtained from the ray flowers in two groups of the common white daisy (*Chrysanthemum leucanthemum* L.), 500 heads growing on rich soil (group A) and 500 heads growing on poor soil (group B) were examined. The specimens were collected on the same day and from localities approximately one mile apart. While the mode (33) and the mean (28.786) were much greater in specimens growing on rich soil (cf. Ludwig, Tower, Shull, etc.) than in those on poor soil (21) (25.632), the index of variability in each group was approximately the same taking into consideration the probable error.

In the second part of the investigation results were obtained from the number of pore-bearing scales in the lateral line of two groups of yellow perch (*Perca flavescens* Mitch.) obtained in Lake Erie. The one group (group A) was procured from a locality (cove in Sandusky Bay) where there was every reason to believe that

*Reprinted from *Science*, N. S., vol. 25 (1907), p. 728.

the food supply approached the maximum, while the other (group B) was collected from the rocky shores of an island some ten miles distant where the food supply apparently approached the minimum. Again the index of variability showed no decided difference when the probable error was considered.

In connection with the ray flowers of the daisy it is of interest to note that specimens from rich soil exhibited a tendency toward an even number of ray flowers, while those from the poor soil had a tendency toward an odd number of ray flowers. This however may be a coincidence, although taken into consideration with the differences, a somewhat remarkable one. No decided tendency toward the Fibonacci series was apparent.

The computations were made by the ordinary method, checked by logarithms and a Burroughs adding machine. There are a number of possible errors minimizing the value of the results. These, together with the literature bearing upon the subject will be considered in the final paper.

While the above results suggest that food supply does not materially affect variability, it is evident that work upon a larger number of specimens, as well as carefully controlled experimental investigations, where the effects of different groups of stimuli may be segregated, will be necessary before any final conclusions may be drawn.

LAND PLANARIANS IN THE UNITED STATES*

Leidy, at a meeting of the Philadelphia Academy of Science, August 12, 1851, presented a paper in which he described the first and only species of land planarian (excluding *Placocephalus kewensis*, an introduced form living in hot houses) which has thus far been found in the United States. To this he gave the name *Planaria sylvatica*. The five specimens he obtained were collected under flower pots, boxes, etc., in gardens at Philadelphia, and under pieces of bark, and old logs in the woods bordering Wissahicon Creek. On October 7 of the same year, after a more critical study of the specimens, he proposed a new genus for their reception, the name thus becoming *Rhynchodemus sylvaticus*. At a meeting of the society on August 24, 1858, he again referred to the subject stating that since 1851 he had found one specimen in the western part of Pennsylvania on Broad Top Mountain (August, 1857) as well as several specimens at Newport (July, 1858). Since this time no further observations concerning the collection of additional land planarians in the United States have appeared.

Consequently the occurrence of two distinct species of *Rhynchodemus* at Gambier, Ohio, is of considerable interest. The first form which may prove identical with the examples procured by Leidy at Philadelphia, was found on the partially decayed stem of a Virginia creeper, July 9, 1904, near Bexley Hall. Five specimens were obtained, while additional representatives have been found at the same place each succeeding summer. During November of the past year a single specimen was also taken under a stone in a meadow some three miles south of the preceding locality. The specimens mentioned agree closely with the description given by Leidy as well as with his drawing of the Philadelphia forms published in Girard's paper on

*Reprinted from *Science*, N. S., vol. 25, pp. 732-733.

planarians (*Ann. sc. Nat. Zool.*, 7 ser., pp. 145-310, 1894). The length is greater however, while the anterior part is constricted as figured by Girard for the Newport specimens. It is evident that two and possibly three species were confused by Leidy under the one name. His material was given to Girard and thus far it has been impossible to locate it.

The second form occurring at Gambier is considerably smaller than the preceding one as well as much lighter in color. Only two examples have been found, both under stones in damp woods. It seems quite distinct from any of those taken by Leidy as well as the species tabulated by von Graff in his excellent monograph.

Some papers in preparation dealing with the anatomical structure of the forms will probably make clear their systematic position. Furthermore, it appears evident that land planarians are widely distributed over the United States and that by reason of their similarity to young snails, they have often been overlooked by collectors.

CONTRIBUTIONS TO MUSEUM TECHNIQUE

I. CATALOGUING MUSEUM SPECIMENS^{1*}

An essential feature in connection with a museum, is the maintenance of a careful record or history of the objects forming the various collections, since a specimen deficient in data referring to the locality, date and conditions under which it was obtained, is practically valueless in comparison with one correctly catalogued.²

The inadequacy of the systems commonly employed, even in prominent museums of America and Europe,³ by which rarely more than a number, name, and locality of uncertain value, are more or less heterogeneously arranged in cumbersome and often inaccessible volumes,⁴ is apparent to anyone who has attempted to locate a desired specimen, or when fortunate enough to ascertain the location, to obtain concise information concerning it. This condition of affairs is particularly obvious to the systematist wishing to study the material belonging to a certain group or from a definite area in a museum, for he may indeed be considered a fortunate individual if, after the loss of much time examining the collections on exhibition and in storage, both catalogued and uncatalogued, and in consulting the various volumes in which the data

¹Contributions from the Biological Laboratory of Kenyon College, No. 5.

²I have merely given expression to the principle laid down by Goode in his admirable paper on museum administration (Annual Report of the Museums Association, 1895, also republished in the Annual Report of the Smithsonian Institution, 1897) where he says, "A museum specimen without a history is practically without value and had much better be destroyed than preserved."

³The museums as well as many other institutions abroad, are subservient to precedents which, under the changing conditions, have too often outlived their usefulness. The remarks of Dr. Meyer in a note on a succeeding page (unintentionally on his part) furnish excellent evidence in corroboration of the above statement.

⁴Both the Field Museum of Chicago and the Carnegie Museum of Pittsburgh make use to a limited extent of card or slip catalogues in connection with the book system. From their form and size ($3\frac{1}{2} \times 9\frac{1}{4}$ in the former, $5\frac{1}{2} \times 8$ inches in the latter museum) method of filing, and arrangement of data, however, it is questionable whether a decided advance has been made over the old book catalogue.

*Reprinted from *The American Naturalist*, vol. 41 (1907), pp. 77-96.

are supposed to be kept, he obtains the data which he wishes.¹

Consequently the following suggestions in respect to the cataloguing (often spoken of as 'registering' or 'recording') of specimens have been brought together primarily with a view toward facilitating the maintenance of such records in museums of Natural History, although it is hoped that they may prove of practical advantage in connection with other institutions of a similar nature. The paper was outlined and partially written while engaged in the rearrangement of certain collections in the American Museum of Natural History, New York, during the summer of 1901. The completion, however, although a brief review was published in the *Ohio Naturalist* for 1904, has been delayed in order to make further inquiries concerning the systems of cataloguing used in various museums, as well as for the purpose of profiting by a more extended practical application of the method. This latter result has been accomplished in the cataloguing of specimens during the last three years for a foundation of a small museum at Kenyon College. It may be noted that very few changes from the plan first proposed have been rendered necessary.

The literature relating to the subject of cataloguing museum specimens is chiefly conspicuous by its absence, notwithstanding the mass of information in regard to museums and museum administration which has been brought together in the *Museum Journal* and a few other periodicals devoted to the interests of such institutions, and in the papers by Meyer :00-03, Gratacap :02-03, Murray :04, etc. Meyer (p. 419) briefly outlines the method used in the Field Columbian Museum, while Murray (v. I, p. 264) somewhat naively suggests that "As

¹In a vigorous article by Bather (How may Museums best retard the Advance of Science, Annual Report of the Museums Association, p. 90-105, 1896) some of the difficulties of locating museum specimens are described as follows. "Many years ago I journeyed to Strassburg on purpose to examine certain specimens that had been described by Mr. de Loriol. The various curators whom I met at the Museum assisted me very willingly throughout three days searching for these specimens, but they could not be found, and I went on my way sorrowing. Arrived at Freiburg, I mentioned the fact to my friend, Professor Steinmann, who suggested that possibly the specimens might have been overlooked as being in the Cartier collection. At considerable expense and inconvenience I therefore returned to Strassburg, and sure enough, there were the specimens carefully obscured."

a rule it is of importance that the exact locality from which each specimen has been obtained should be recorded This does not apply to archaeological objects alone The date of finding or acquisition is often likewise of importance."

There are nevertheless a few papers which should be mentioned.

Hoyle, '91, described the cataloguing of specimens in the Manchester Museum and formulated a system of 'registration' in book form, and of 'cataloguing' through the use of cards. His registration catalogue corresponded to that designated in the succeeding pages as The Department Catalogue. It consisted of fourteen volumes bearing reference letters A-O, beginning with A-Mammals, B-Aves, etc., and ending with N-Mineralogy, and O-Anthropology. Each volume contained space for 12500 specimens and was ruled in perpendicular columns so that space for data concerning 'date,' 'name,' 'locality,' and 'remarks,' was afforded. When a specimen arrived at the museum, the first vacant number in the volume corresponding to the group to which the specimen belonged, was affixed to it and the data concerning it noted in the appropriate column. After the specimen was thus 'registered' (*i. e.*, our Department Catalogue) it was further catalogued in what Hoyle described as the "Curators Catalogue" (*i. e.*, our Reference Catalogue) by means of which an official record of the contents of the museum arranged according to a natural classification, was maintained. This is very similar to that which I have termed The Reference Catalogue. It consisted of a buff 'family-card' 5 x 3 1/8 inches, on which the name of the family (*e. g.* Cidaridae) was written, a gray 'genus card' containing the generic name (*e. g.* Cidaris), and a white 'species card' having the specific name (*e. g.* hystrix) and the mode of preservation, the register number (*i. e.* department number), and locality.

The method of registration presents, in comparison with a card system, the usual disadvantages of the book catalogue as noted on a succeeding page. The absence of a practical means of cross indexing the various volumes

by tabs and colored cards representing systematic divisions, geographical distribution, type specimens, etc., is at once manifest. Furthermore no space is given for noting the authority for identification, date collected, etc., name of collector, etc., for all of which data provision should be made.

The "Curators Catalogue" may be criticized on this same basis. Moreover in a catalogue, the chief purpose of which is that of a reference or finding catalogue, there seems every reason for arranging the cards in alphabetical order in preference to classifying on a systematic basis. Hoyle, himself, in noting some objections to the decimal system proposed by Petrie in *Nature*, mentions the fact that "no specialist is ever satisfied with any other specialist's work." Furthermore unless arranged according to the alphabet as suggested under the Reference Catalogue, it would be of no value to the public. The cards adopted should naturally be of a standard size since odd sizes cannot be perfectly cut by reason of the expensive machinery used. Ordinary 'guide cards' would be much better than the 'genus' and 'family cards.'

Dorsey, '99, reviewed the method of cataloguing used in the Field Columbian Museum of Chicago. As suggested in a preceding footnote, this appears to be more or less of an heterogeneous arrangement of cards, books, and manila envelopes, which could be much simplified.

Walton, :04, published a brief outline of the present paper noting the division into (a) The Accession Catalogue, (b) The Department Catalogue, and (c) The Reference Catalogue, as well as suggesting the general scope and methods of filing the cards employed in each.

Wray, :05, called attention to the adoption of the card system in the Perak Museum of the Federated Malay States, a result brought about by the unsatisfactory nature of the book method of cataloguing. A single type of card (3 x 5 inch) was used. This contained the following data: 'Accession No.,' 'Date when received,' 'Place in Museum,' 'Description of Specimen,' 'Where procured,' 'How obtained,' 'Presented by,' 'Bequeathed by,' 'Purchased from,' and 'Collected by.' Duplicate cards were

made out, one set being filed numerically as a 'Register,' the other according to the arrangement of the specimens in the museum (each museum case being given a number, and each gallery a letter, e. g. 17F) as a 'Catalogue.' The 'Register' evidently corresponds to that which I have designated the 'Department Catalogue,' lacking the method of cross indexing by departments, marginal tabs, and colored cards (when desirable). The 3 x 5 inch cards used by Wray are too small, while the writing of two sets for each specimen nearly doubles the clerical work involved in the use of an Accession, Department, and Reference catalogue as noted in the following pages, since by the latter method a large number of specimens are usually transcribed on a single department and reference card. Space for certain valuable data is likewise omitted by Wray, something unavoidable however with the small card.

From the first it seemed evident that the card catalogue arranged in unit cabinet sections would furnish the most satisfactory solution of the problem. The value of such a system had long ago been recognized in connection with library and general business methods, where it rapidly displaced the bulky volumes formerly considered necessary to contain various records. The advantages resulting from the use of the card system are obvious, since (1) the required data are presented in a compact and easily accessible form; (2) the capacity is unlimited, useless records can be taken out or new ones added; (3) by varying the position of the tab¹ on the upper margin of the card, as well as by using cards of different colors, a variety of cross reference systems may be employed; furthermore, (4) the form of the card allows the condensation of matter which would extend across one or more pages in a catalogue.

The standard sizes of cards² manufactured in America, are 3 x 5, 4 x 6, and 5 x 8, inches, and although other sizes could be made and used, it is well to adopt one of these, inasmuch as the regular card cabinet section can

¹The word 'tab' is the term applied to the projecting portion of the upper margin of the card.

²The 'standard size' (No. 33), adopted by the American Library Association in 1878 for library use, is 125 x 75 mm. ($2\frac{61}{64}$ x $4\frac{59}{64}$ in.).

thus be employed as a unit and the special machinery used is particularly adapted for the three sizes. The 3 x 5 inch cards are too small, and for general purposes the 5 x 8 inch cards are too large and unwieldy. The 4 x 6 inch card, however, is of sufficient size to contain all necessary data, without being cumbersome in manipulation.

Card cabinets to contain the catalogues may be obtained in various sizes, but by the adoption of the 'unit' card index section containing six drawers adopted for the 4 x 6 in. card, future units may be added as occasion demands, and the cabinet is thus always complete.

Following a chronological order, the data which should be rendered accessible in an adequately catalogued collection, can be separated into three divisions. These are: (A) The Accession Catalogue, containing a general record of all material received by the museum. (B) The Department Catalogue, giving a complete history of each specimen or group of specimens, (a single species, acquired by each department). (C) The Reference Catalogue, having the names of all specimens belonging to each department, arranged alphabetically so that the final disposition of any desired specimen can at once be ascertained.

Of these, the Accession and Department catalogues are essential from a business as well as a scientific standpoint, while the Reference catalogue, although not a necessary requisite, will be found advantageous as a reference index to the specimens, particularly in the larger museums. With the exception of the one pertaining to accessions, which should be in charge of the director of the museum, each catalogue should be controlled by the head of the particular department with which it deals.

While the records considered necessary vary more or less in connection with the needs of the institution and department concerned, they can in general be reduced to the following tabular form, covering the data which may be required in Museums of Natural History.

- A. Accession Catalogue (arranged numerically)
 - 1. Accession number.
 - 2. Date received.
 - 3. Description.
 - 4. How obtained.
 - a. Purchase (cost).
 - b. Gift.
 - c. Exchange.
 - d. In trust.
 - e. Museum collectors.
 - 5. From whom received.
 - 6. Address.
 - 7. Transportation number.
 - 8. Collector.
 - 9. Locality where collected.
 - 10. Date when collected (approximate).
 - 11. Correspondence filed under.
 - 12. Remarks.
 - 13. Date of entry.
- B. Department Catalogue (arranged numerically).
 - 1. Department number.
 - 2. Accession number.
 - 3. Original number.
 - 4. Number of specimens.
 - 5. Sex.
 - 6. Stage of growth.
 - 7. Scientific name.
 - 8. Authority for identification.
 - 9. Date of identification.
 - 10. Locality where collected.
 - 11. Name of collector.
 - 12. Correspondence.
 - 13. Date when collected.
 - 14. Character of specimens.
 - 15. Remarks.
 - 16. Date of entry.
- C. Reference Catalogue (arranged alphabetically).
 - 1. Name of specimen (common name and scientific name,—genus, species,—listed on separate cards).
 - 2. Department number.
 - 3. Character of specimen.
 - 4. Location.
 - a. On exhibition. Case No.
 - b. In storage. Drawer No.
 - 5. Number of specimens.

The following suggestions have been found valuable in regard to the data and their arrangement on the cards.

A. ACCESSION CATALOGUE

In this catalogue, all material¹ received or collected at a particular time from a particular source, (an accession), is placed under a single accession number. Thus the catalogue will contain a record of each group of specimens coming into the possession of the different departments in the museums, and by means of a series of cross references, consisting of tabs arranged as indicated in the accompanying illustration, it will be possible to ascertain at any period the data concerning the accessions acquired by each department, whether they have been obtained by purchase, gift, exchange, through museum collectors, or in trust, and if by purchase, their cost, as well as the particular fund made use of in connection with their acquisition.

The disposition of each item on the card should correspond to its relative importance. In the following diagram a convenient arrangement is suggested.

Classification by Departments.—A classification by departments can be conveniently maintained by having tabs arranged on the cards in as many different positions as there are departments. Thus with $\frac{3}{4}$ inch tabs, eight departments may be tabulated.

Accession number.—This should occupy a prominent place, preferably the upper left hand corner, and in order that it may be easily noted, should be written in a large plain figure with black or red ink.² The numbers should be serially arranged in accordance with the date of arrival of the accession, and at intervals of one hundred cards, a numbered guide card of a particular color (*e. g.* dark blue) may be inserted. Where no previous catalogue of this nature has been kept, it may be well to have new accessions commence with a number sufficiently large

¹While it is equally the same whether one specimen or one million specimens are received, the terms 'particular time' and 'particular place' are necessarily subject to considerable latitude in their interpretation. If certain systems of cross references are used it may be necessary to place a collection under several different accession numbers. For example, if cards of various colors represent geographical distribution (*e. g.* Nearctic, etc.), it would be necessary to use as many accession cards as there were regions represented in the particular collection.

²It is perhaps unnecessary to remark that in records of this nature india ink should always be employed and cards of the best quality be used. Inks made of aniline colors will fade within a few years.

(e. g. 1001) to allow the eventual cataloguing of former collections which have come into the possession of the museum¹ in a manner as nearly chronological as possible.

Date received.—The most convenient formula for expressing the date on which an accession is received, is the use of an Arabic numeral for the day of the month and a Roman numeral for the month, followed by the year (e. g., 6-IX-1898=September 6, 1898). The usual place for the date is the upper right hand margin. At the end of every year, a card can be inserted, on the tab of which the particular year is indicated. Thus the material obtained by the museum during any particular period is at all times readily ascertained.

Description of material.—The general nature of the consignment should be indicated, (e. g. archaeological material, mammal skeletons, fishes) as well as the manner in which it is packed (number of packages, boxes, etc.). In this connection a record should also be kept as to whether the accession is received as a 'purchase,' 'exchange,' 'gift,' 'in trust,' or through 'museum collectors.' This can be readily accomplished by having the above words written on the card and placing a cross in the proper space at the time of cataloguing. When procured by purchase, the price should also be indicated.

From whom received.—The name and permanent address of the person sending the specimens, is to be noted here.

Transportation number.—It is often convenient to have a record of the number or numbers placed upon the consignment by the transportation companies, particularly in the event of breakage or loss of any of the contents of a package or box.

Name of collector.—Many collections are deficient in labels bearing accurate information, consequently it is advisable to ascertain the names of individuals concerned in collecting the specimens, so that if desirable, further

¹When accession catalogues have been maintained separately by the departments, the numbers in the new catalogue must be of a higher order than the sum of the previous ones used, provided it is desired to maintain the approximate chronological order.

data may be obtained. The address of the collector is to be noted, provided it differs from that of the locality where the collection was made.

General locality.—When the collection is a small one from a restricted locality, this can be readily indicated. If, however, a large amount of material is represented, the principal region or regions should be given.

Date when collected.—It is necessary to indicate merely the approximate time.

Correspondence.—In order to readily refer to correspondence, invoices, bills, and other memoranda relating to the accession, it is well to indicate the initial name or number, together with the year, under which they are filed.¹

Remarks.—Under this heading can be noted the condition of the specimens, whether or not the collection contains any forms of particular value (types, cotypes, etc.), as well as other general information.

General suggestions.—In order to record small collections, which may come directly to a department, blank cards may be provided for those in charge, and upon the arrival of such an accession, these should be immediately filled out and handed to the person keeping the Accession Catalogue. Blank cards to be similarly filled out and returned, can be sent to a person from whom an accession deficient in data is received. The system of cross references can be arranged to meet any demand. The method employed as noted above, appears adequate for ordinary purposes. Thus the name of each department is placed on a tab assigned to a particular position, and when the cards are filed, the accessions of a department will be indicated by the corresponding row of tabs. A further subdivision which may be applied to each department is in the use of colored cards. If for example the department of anthropology, possesses three separate appropriations upon which to draw for as many purposes, *e. g.*: (a) Explorations on the North Pacific Coast. (b) The purchase

¹Madeley :04 presents an elaborate arrangement for the classification of office papers in Museums based upon a provisional decimal system. It seems unfortunate that the standard decimal system (Dewey) was not utilized.

of Michigan Antiquities, and (c) Collections illustrating the life of the Aztecs; all accessions in Anthropology of (a) obtained by purchase, or at the expense of the museum from the one fund, can be placed on salmon colored cards, while similarly all accessions of (b) and (c) obtained from the corresponding appropriations can be placed on buff and blue cards, respectively. Thus at any time the general condition of the various funds of the department can be readily ascertained. Geographical Distribution (*e. g.* nearctic, neotropical, etc.,) may be represented in a similar manner.

Placing numerical guide cards at intervals of every hundred cards, will greatly facilitate finding any desired accession number. In a catalogue where the width of the tabs makes it possible to have an area at the right from which no tabs project, it is convenient to place the numerical tab as in Fig. 1.

Inasmuch as the majority of accessions cover a quantity of specimens, such a catalogue as the one described can be easily maintained, and the advantages which result through always having correctly classified data accessible are an important item in the making up of reports.

B. DEPARTMENT CATALOGUE

The department catalogue has the cards arranged numerically in chronological order and should contain concise information concerning each specimen, or group of specimens belonging to the same species which were obtained at a definite time and place. In the smaller museums the material may be grouped under departments of Zoology, Botany, Palæontology, etc., as represented by the Accession Catalogue each with its separate department catalogue. In the larger museums, however, it will often be advisable for each department to have several sub-departments or group catalogues having the rank of departments. For example the department of Zoology may maintain catalogues of Vertebrate and Invertebrate Zoology, or of Pathological preparations, Neurological specimens, etc., or on a systematic basis it may have a catalogue for each phylum or branch of the animal and plant

kingdoms. The cross-reference classification by means of tabs, however, as represented in the department catalogue will usually be sufficient in the smaller museums.

Here the arrangement of data will meet the needs of the average department. Near the middle of the upper margin of the card should be placed the name of the particular department to which it refers, together with the name of the institution. If the department is large so that group catalogues are necessary, this should also appear, *e. g.* Zoology Department Catalogue, South African Museum, Birds.

Systematic cross reference classification by tabs.—The classification adopted will depend on the nature of the catalogue. If half-inch tabs are used on a 6 inch card twelve divisions are possible which in the zoological department cards above consist of 1. Mammals, 2. Birds, 3. Reptiles, 4. Amphibians, 5. Fishes, etc., 6. Tunicates, 7. Echinoderms, 8. Articulates, 9. Mollusca, 10. Vermes, 11. Coelenterates and Sponges, and 12. Protozoa. For certain reasons an arrangement in the reverse order would be more logical. In a botanical catalogue one could choose between the older classification of Eichler, 1883, where a somewhat arbitrary grouping gives us the 1. Algae, etc., 2. Lichens, 3. Bryophytes, 5. Ferns, 6. Gymnosperms, and 7. Angiosperms, and the recent one of Engler,¹ 1904, with thirteen groups and 35-40 classes. The classification adopted in the other department catalogues, Palæontology, Anthropology, etc., will in a similar manner represent to a more or less extent the personal equation of the curator under whose supervision they are maintained.

Geographical cross reference classification by colors.—Geographical distribution may easily be indicated by having cards of a particular color represent definite areas. Such an arrangement does not appear to render the card system so complex that it is disadvantageous, although over-systematizing is a danger which confronts any general method.

If the collection is local in its character, the majority of specimens being obtained from a given state, an excel-

¹Engler, A. 1904. Syllabus der Pflanzenfamilien, 4th edition, Berlin.

lent arrangement is that of having all specimens from the county in which the collection is located, catalogued on white cards; all specimens from the state excluding the county, catalogued on buff colored cards while other specimens from localities outside of the state would be catalogued on salmon¹ colored cards. In the larger museums where collections are made up of specimens from different parts of the world, certain colors can be used to represent various regions, (nearctic, neotropical, palaearctic, etc.). Types, cotypes, etc., could be catalogued on cards having the right half red, the left half in accordance with the color representing the particular geographical distribution.

Department number.—A single department number will cover a series of specimens of the same species, which have been obtained at the same time in a particular locality. This method is more satisfactory than assigning a number to each individual specimen inasmuch as time would be lost by such a method and no particular benefits result. Should the occasion arise at a later period, a separate number may be assigned to any specimen.

Accession number.—This should be indicated on the card, in order that general information regarding the collection may be obtained at any time. The accession number and department number may be indicated in connection with the specimens as a fraction (*e. g.* $294\frac{4}{896}$) whose numerator represents the accession number, and denominator the department number, or as a decimal (294.896), or the accession number may be entirely omitted from the specimens, since a reference to the department card will furnish it when desired.

Original number.—This is the number which a specimen may possess on its arrival. Often times it will be the field number placed on it at the time when it was collected or it may refer to a number assigned in a previous collection.

Number of Specimens.—This is essential in order to know the amount of material in any collection. When

¹These colors are suggested inasmuch as the majority of manufacturers of cards in the United States make them in four standard colors, white, buff, salmon, and blue.

duplicates are used for exchange, the former number should be crossed out and the new one substituted, while, at the same time, a reference number referring to the exchange may be added.

Sex.—The sex can be designated by the conventional signs, ♂, ♀, ♂, representing male, female, and hermaphrodite forms.

Growth. — Embryo, young, adult. Measurements, weight, etc.

Scientific name.—In systematic work of this nature the generic followed by the specific name must be used.

Authority for identification. — This is an important item which is too often omitted from the average museum catalogue. If a specialist subsequently verifies a name previously given, this should also be noted. In case the name is found incorrect a new card is to be written.

Date of identification.—It is well to have this information available.

Locality where collected.—Too much care cannot be exercised in accurately indicating the locality from which specimens are obtained. It is safe to say that every museum has among its collections material which would be of utmost value, provided the locality, even within a few hundred miles, could alone be ascertained. Unfortunately in most cases of this kind, it is the collector who is at fault. The cataloguer must rely on his data.

Name of collector.—Inasmuch as the 'personal equation' must be taken into consideration, the name of the collector is indispensable. Furthermore, it often furnishes a clue to the history of a specimen when all other means have failed.

Correspondence.—Letters, etc., pertaining to the particular specimens can be indicated as suggested in the accession catalogue.

Date when collected.—This can be indicated as in the accession catalogue.

Character of specimen.—The nature of a specimen, whether a skeleton, an anatomical preparation, a mounted skin, etc., should be given. If preserved in a special manner it is well to indicate the formula, *e. g.* 5% formalin; 70% alcohol; killed and hardened in chromosmic 3 hours, preserved in 95% alcohol, etc. Explicit notes here will in the end well repay the time spent in making them. The back of the card will afford additional space, if needed.

Remarks.—This space is only to be filled out when there is something of particular importance to be noted concerning the specimen, and of a nature which cannot be covered under the other records.

General suggestions.—The data, as well as their arrangement on the cards, are naturally subject to various changes, in order to conform to the requirements in different museums. It is well to have a blank space for each item of information concerning the specimen, although often unnecessary, or even inadvisable, provided there is reason to doubt its accuracy, to fill it out. As in the Accession Catalogue numerical guides should be placed at intervals of one hundred cards, while 'side locking cards' are recommended.

C. REFERENCE CATALOGUE

The Reference Catalogue may with equal propriety be termed a finding list, since its purpose is that of indicating the location of each specimen which belongs to the particular department in the museum. The cards are arranged in alphabetical order, both the scientific name (generic followed by specific name in the case of biological specimens), and the common name having a place on separate cards, the latter, however, referring to the former, (*e. g.*, opossum, see *Didelphys*). Furthermore, the reference card indicates the number of specimens of each species on exhibition, or in storage, giving the number of the case or storage drawer in which they are to be found.

A single card will usually contain the data concerning all material belonging to a particular species, consequently the time involved in maintaining a Reference Catalogue

is an unimportant item, the data (except location of specimens) being readily obtainable at any time from the Department Catalogue.

The Reference Catalogue should be located in the principal room containing the collections to which it refers, where it will be readily accessible to each of the three classes of people for which a museum primarily exists: (a) the specialist, (b) the amateur, and (c) the general public.¹

One method for arranging the data for a reference catalogue, is shown below.

Systematic Cross Reference Classification by means of Tabs.—An excellent method which meets the usual requirements, is that of having the tabs arranged as in the Department Catalogue. Geographical cross reference by colors cannot be used inasmuch as one card will often contain specimens from widely separated localities.

Name of specimens.—Both the scientific name and the common name should be given, the former on the card containing the data, the latter on a separate card referring to the generic or specific name of the particular species. (e. g. Brook Trout, see *Salvelinus fontinalis*, Pickerel, see *Esox*, various species.) By placing the common name on cards having a particular color they may be readily distinguished.

Department numbers. — Inasmuch as the department numbers will be placed on all material, this will serve to establish the identity of the specimen sought, and in case further data is required, the corresponding number in the Department Catalogue can be consulted.

Character of Specimens.—In alcohol, mounted, skeleton, skin, etc.

Exhibition, Storage, etc.—The location of a specimen is indicated by the particular column under which it is placed. If on exhibition, the number or letter of the

¹See Bather, F. 1904. The Functions of a Museum; a Re-Survey. Pop. Sci. Mo., v. 64, p. 210-218.

case¹ will be given. Alcoves or galleries may be designated by letters. If in storage, the location will be similarly designated.²

Total number of specimens.—These columns will indicate the total number of specimens of a given species³ belonging to the museum. If customary for the institution to make exchanges a balance column may be added, which will show the material on hand as well as that exchanged.

The necessary steps incident to the cataloguing of a collection which has been received may now be outlined as follows.

- a. Catalogued as an Accession.
- b. Placed in charge of a department.
- c. Catalogued in a Department Catalogue and given a department number.
- d. Identified and labelled. This data then added to the department card.
- e. Placed on exhibition or in storage.
- f. Reference Catalogue filled out from data on department card.

The first three items should be attended to at once. A considerable interval will often elapse, however, before final disposition of the specimen is made.

It would seem that only two general objections can be urged against any system similar to the one proposed, namely; (1) The plea that too much time will be occupied in the preparation of such a catalogue, and (2) a certain inherent condition which precludes the adoption of new ideas. The only answer that need be given to the former is that the space occupied by a specimen unworthy of being properly recorded, is more valuable than the specimen itself, while to the latter no reply is needed.

It is unnecessary and often inadvisable to at once reduce

¹If the case is a large one and contains a quantity of specimens, it may be convenient to indicate the number of the shelf, etc.

²The practice of having separate department catalogues for the exhibition and storage series, is to be criticized. Different species thus possess identical numbers, and when it becomes necessary to transfer a specimen which has outlived its usefulness for exhibition purposes, to the storage collection, complications at once ensue.

³When it becomes desirable to include a collection in a guide book to the museum or to issue a general catalogue of the specimens, the question involved is merely that of selecting the data here classified.

former catalogues to a card system. Incoming material can be catalogued on the cards, and as the opportunity allows, data from the previous records can be transferred to cards.

Conservatism¹ is a valuable factor in connection with all scientific work. It has its limitations, however, and in order to make definite progress in any direction, old methods must give place to new ones — the fittest will survive.

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¹Meyer, (:00-01) in his excellent review of the museums of the eastern United States depreciates the lack of uniformity among the various American museums in respect to the installation of the collections. In reply to this criticism however it might well be suggested that to a certain extent at least this lack of uniformity is an indication of healthy activity. It is not considered necessary in this country to cling to traditional ideas which are too often brought to the attention of one visiting European museums. New methods of dealing with well known problems are sought and evolved—and if their value is proven—they are adopted.

Since the above paragraph was first written (Aug. 1901) Dr. Jordan in his presidential address before the members of Sigma Xi (Dec. 31, 1903) expressed similar ideas regarding this tendency which he had noted. "In France, in Germany, even in England, the tradition of great names, the customs of great museums, largely outweigh the testimony of the things themselves. The willingness to adopt new ideas is, broadly speaking, in proportion to the spirit of democracy by which a worker is surrounded."

THE VARIABILITY OF ZYGOSPORES IN *SPIROGYRA QUADRATA* (HASS.) FORMED BY
SCALARIFORM AND BY LATERAL
CONJUGATION, AND ITS BEARING
ON THE THEORY OF
AMPHIMIXIS*

With the object in view of obtaining data bearing upon the purpose of *amphimixis*, and the causes tending to produce *variability*—problems which have long remained most elusive in everything except theory—a biometrical investigation in respect to the comparative variability and correlation in 400 zygospores of *Spirogyra quadrata* (Hass.) formed by scalariform and by lateral conjugation was undertaken.

In the first instance (scalariform conjugation) we deal with the results of conjugation between remotely related cells belonging to different filaments. In the second instance (lateral conjugation) we deal with the results of conjugation between sister or adjacent cells of the same filament, a condition closely related to the phenomena of parthenogenesis in other organisms. If the conjugation of germ cells from remotely related individuals tends to variability as Weismann and others would have us believe, conversely the union of closely related cells should afford a decreased variability, the minimum appearing in parthenogenetic forms.

The results show a condition directly contrary to this, the zygospores of lateral conjugation being approximately 21 per cent more variable in length and 31 per cent more variable in diameter than those produced by scalariform conjugation. Consequently, direct evidence is afforded

*Reprinted from *Science*, N. S., vol. 27 (1908), p. 907.

in support of the theory of Hatschek (1887) that sex exists for the purpose of limiting and not for the purpose of increasing variability.

A comparison of constants, the general discussion, methods of measurements, as well as a review of the literature, particularly papers by Warren, Kellogg, Pearson, etc., will be given in the completed paper.

SYMBIOTES DURYI, A NEW SPECIES OF
ENDOMYCHIDAE¹*

(Contributions from the Biological Laboratory, Kenyon
College, No. 7.)

The genus *Symbiotes* of the family Endomychidae belonging to the Coleoptera has prior to the year 1908, been unrepresented by any described species from North America although Leconte and Horn (1883) erroneously referred *Rhymbus ulkei* Crotch, and *Rhymbus minor* Crotch, to this genus in their classification of the Coleoptera of North America.

Consequently it was with much interest that the writer in November, 1907, collected two specimens at Gambier, O., which through acquaintance with the European representatives of *Symbiotes* were immediately referred to that genus. This occurred only a few days prior to the annual Thanksgiving meeting of the Ohio Academy of Science at Oxford, presided over by the President, Mr. Charles Dury, of Cincinnati, an indefatigable collector of Coleoptera as well as a keen student of nature. It therefore seemed most appropriate that the name *duryi* should be conferred upon the species which had so opportunely presented itself, an idea which was carried into effect at the meeting, the specimens also being exhibited.

This was noted in the Proceedings of the Academy for 1907 (mailed about June 1, 1908). Blatchley, (1910), after communicating with the writer as to the systematic arrangement of the Endomychidae and the generic characters of the genus *Symbiotes* for his forthcoming paper on the Coleoptera of Indiana, gave a description of "*Symbiotes duryi* Walton MS" (p. 536) in that most excellent report. The collection and study of representatives of

¹Read before the meeting of the Ohio Academy of Science, Columbus, December 1, 1911.

*Reprinted from *The Ohio Naturalist*, vol. 12 (1912), pp. 461-464.

the genus however, had not at that time proceeded sufficiently so that the description is of value in differentiating this species from the several other species of *Symbiotes* occurring in North America.

The genus was founded by Redtenbacher in 1849 for the reception of *S. latus* the generic name being based on the supposition that the species was myrmekophilous. While at times *S. latus* as well as other European forms appear to have been found in association with ants, it is evidently not characteristic in general of the species and the actual habitat is rather one of association with the lower forms of fungi on the spores of which the individuals feed, as noted in another part of the present paper.

Only six species of *Symbiotes* have thus far been described, three from the European region, two from Japan, and one from South America.

The two representatives of the species which have been found were taken under a slightly decayed hardwood log near the south side of the "Hotel Hill" road bridge at Gambier, the log being partially covered with one of the lower forms of fungi, in the spores of which the *Symbiotes* feed. In accordance with other representatives of the genus, the species is exceedingly small, being less than 2 mm. in length. The drawings below indicate certain anatomical details. The description follows:

Symbiotes duryi n. sp.

CHARACTERS.—Form more or less broadly oval, moderately convex, scarcely pubescent, color dull testaceous; head scarcely punctuate, antennae with club moderate in size, 1. segment large, 2. segment narrow but of approximately the length of the 1. segment and equal to the 3. and 4. together, 3.-8. subequal in length but slightly increasing in diameter, 9. larger, triangular, 10. transverse, about three-fourths as long as the 9., 11. asymmetrically pointed. Prothorax twice as wide as long, strongly rounded anteriorly, broadest at middle, margins toothed, median region convex, base with a strong transverse sulcus from the lateral portions of which extend on each side triangular longitudinal sulci reaching anteriorly about half the length of the prothorax.

Elytra short, oval, decidedly broader than the prothorax, attaining their greatest width about one-fifth of their length from the base; punctures arranged in more or less confused rows; subsutural striae broadly curved at the scutellum and attaining the middle of the base of the elytra; composed of extremely large punctures which reach their maximum size near the scutellum.

Length 1.9 mm.

DISTRIBUTION.—Gambier, Ohio, (U. S. A.).

The species is easily distinguished from its nearest ally *S. gibberosus* Lucas, of Europe, and from other undescribed North American species, through the comparatively much broader elytra and the extremely large punctures near the scutellum in the subsutural striae. Furthermore it is darker in color, and there is a difference in the arrangement of the ordinary elytral striae.

One of the specimens was partially dissected which afforded an opportunity of observing the contents of the digestive tract. This was found to contain a mass of minute spores each somewhat oval in form and 10 mic. in length. The entire tract from the mid portion of the metathorax was filled with the spores, and by counting the number in a given area, an approximation of the total gave 13,500 for the number in the tract. Unfortunately the fungus with which the species was in association was not collected, so even the family to which it belonged cannot be noted with certainty.

It seems certain that *Symbiotes* will be found widely distributed in North America.

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AMPHIMIXIS, VARIABILITY AND DEATH; SOME FACTS AND A THEORY*

In connection with some studies on the variability of zygospores in *Spirogyra inflata* (Vauch.) formed by scalariform (amphimixis) and by lateral (quasi parthenogenesis) conjugation, certain facts are presented which allow an interpretation of the cause of death among organisms from a different standpoint than the generally accepted theory.

In 200 zygospores produced through the conjugation of cells of different filaments—sexual reproduction—the coefficient of variation is 9.5093 for length and 5.7471 for diameter. In the same number of zygospores produced by the fusion of adjacent cells of the same filament—comparable to asexual reproduction—the coefficient of variation is 11.9364 for length and 7.5376 for diameter, indicating for the given conditions that the cross-bred or sexually-produced zygospores, in themselves the young individuals from which the mature filaments arise, are relatively 20 per cent less variable in length and 23 per cent less variable in diameter.

Thus if amphimixis decreases variability, there is presented an interesting condition bearing not only on the problem of the origin of sex, but also on the origin of death, for the theory is equally applicable to the individual cell, whether isolated, as in the Protista, or associated in colonies, as in the higher animals and plants. The development of the body in multicellular organisms represents merely the development by asexual reproduction of an infinite series of cell individuals. Consequently the evidence suggests that *death occurs as the result of the continually forming body cells becoming so variable through the absence of control by amphimixis, that eventually some one group fails to meet the limits im-*

*Reprinted from *Science*, N. S., vol. 35 (1912), p. 935.

posed by the environment, and these together with the remainder of the colony—the individual—perish.

With a single exception, the available evidence is directly in accord with such a theory, although in general merely demonstrating that amphimixis does not increase variability (Warren, '99; Castell and Phillips, '03; Kellogg, '06; Wright, Lee and Pearson, '07). The investigations of Jennings, '11, on *Paramecium* seem to indicate that here conjugation increases variability. The evidence, however, was not altogether in harmony, in consequence of which the subject was reserved for a future paper based upon additional investigations. Even granting that such is the case in *Paramecium*, where conjugation consists of a temporary union of gametes (conjugants), it would not necessarily follow that a similar condition would be found in organisms where a total and permanent fusion of gametes (copulants) occurred.

While it would seem that such a theory as here outlined is in advance of the earlier theories as to the cause of death which are purely speculative, there is need of additional data, and it is hoped that the several investigations now in progress may throw additional light on the subject.

THE LAND PLANARIANS OF NORTH AMERICA, WITH A NOTE ON A NEW SPECIES*

Since calling attention to the rediscovery of *Rhynchodemus sylvaticus* described by Leidy in 1851¹ the species has been found in abundance not only in Gambier but also at Urbana, O., and Meadville, Pa. The material from which the species was originally described was placed at the disposal of Girard by Leidy for study in connection with the former's paper on the planarians of North America.² Inasmuch as the specimens were in the possession of Girard at the time of the death of Leidy³ and were given him for use as he deemed best, it is quite probable they are in the possession of some of the European museums, if in existence. Thus far it has been impossible to locate them, however.

Two specimens of a much larger species approximating 20 mm. in length and uniformly dark blue in color have also been taken in Gambier. For this the name *Rhynchodemus atrocyaneus* is proposed.

The land planarians of North America and the adjacent islands may be tabulated as follows: *Geoplana nigrofusca* (Darwin), Mexico and South America (common). *Geoplana stoll*i Graff, Guatemala (a single specimen known). *Placocephalus kewense* (Mosley), cosmopolitan in hot-houses, original habitat unknown (common). *Rhynchodemus sylvaticus* Leidy, East. U. S. (common). *Rhynchodemus atrocyaneus* Walton, Ohio, central U. S. (?) (two specimens known). *Amblyplana cockerelli* Graff, Jamaica (a single representative).

Land planarians occur under slightly decayed pieces of board, sticks, etc., particularly in grassy plots of old orchards, or lawns, usually in association with snails, the young of which they superficially resemble. The anatomical structure of the Ohio forms is being studied.

¹*Ohio Nat.*, p. 254, 1904.

²*Ann. Sci. Nat. Hist. Zool.*, p. 145, 1894.

³*L. c.*, p. 153.

*Reprinted from *Science*, N. S., vol. 35 (1912), p. 940.

STUDIES ON THE MOUTH-PARTS OF *RHYPAROBIA MADERIÆ* (BLATTIDAE) WITH A
CONSIDERATION OF THE HOMOLOGIES
EXISTING BETWEEN THE APPENDAGES
OF THE HEXAPODA*

The question as to the homologies existing among the paired appendages of the Hexapoda has received attention from various investigators, and in particular from Hansen, Heymons, Börner, Verhoeff, and Escherich, none of whom however have progressed far toward a satisfactory solution of the problem. In general it has been accepted that the stipes and mentum correspond to the thoracic and abdominal coxae while the maxillary and labial palpi were equivalent to the trochanter, femur, etc., or the functional leg.

Studies on *Rhyparobia maderiæ*, the giant cockroach from Panama, particularly of 10mm. and 12 mm. embryos, as well as other investigations in connection with the appendages of the Thysanura, make it evident that the typical appendage (mouth-parts, thoracic, abdominal, caudal) of the Hexapoda consists of seven definite areas best represented by the maxillæ with the galea, lacina, ectostipe, endostipe, ectocardo, endocardo, and palpus. Furthermore the palpus should be homologized with the stylus of the thoracic and abdominal coxae and not with the functional leg, inasmuch as both palpus and stylus are appendages of homodynamous areas (ectostipe, ectomentum, meron) while the leg is an appendage of the area (endocoxa) corresponding to the endostipes.

The facts noted suggest the origin of the biramose appendage of the Hexapoda directly from the parapodium of the Polychaeta, the notopodium and neuropodium

*Reprinted from *Annals Entomological Society of America*, vol. 6 (1913), pp. 132-133.

arising in connection with the dorsal and ventral bundles of setæ and corresponding to the outer (ectal) and inner (endal) groups of sclerites as outlined above. It would thus appear that the Arthropoda are a polyphyletic group, and that the relationship between the appendages of the Hexapoda and Crustacea is a more remote one than generally accepted in connection with the studies of Hansen and Börner.

The historical development of the problem as well as the presentation of the facts which would seem to establish the views here advanced, will appear in the completed paper of which this is a partial summary.

Discussion: W. A. Riley—I have been especially interested to learn that Dr. Walton is swinging away from his earlier belief in the double nature of the insect segment. It has seemed to me that embryological data afforded no evidence in support of the theory though there are indications of the biramous nature of the appendages. The theory of the origin of the insect appendages from the pleuropodes receives much additional support from the work here presented.

THE EVOLUTIONARY CONTROL OF ORGANISMS AND ITS SIGNIFICANCE^{1*}

I.

A comparatively brief period has passed since the evidence brought together by Darwin in connection with the results slowly accumulated from other sources has clearly demonstrated that the diversity of organic life in the world occurs through evolution. It is one thing, however, to clearly diagnose a condition and quite another to understand the causes which have brought about the phenomenon so that similar results may be produced advantageously. With the assumption that evolution was merely the survival of those forms which were best adapted to the environment, generation after generation, the explanation of the method as well as its practical application, namely the improvement of organisms in any given direction, was apparently a simple matter. It seemed evident that man had modified and adapted to his welfare various plants and animals by a more or less unconscious and haphazard selection long before history records civilization.² Why then could not civilized man carry forward the work and with the knowledge gained since the principles of evolution were recognized, obtain far-reaching results within a brief period of time. All that seemed necessary was to have individuals of a particular organism in large numbers, and by continued selection of the variations best meeting the conditions move rapidly forward by a series of increments toward the goal of perfection. What could be more simple? Instead of corn having an

¹Presidential address before the twenty-third annual meeting of the Ohio Academy of Science, Oberlin, O., November 28, 1913.

²One need not be a pessimist to assert the actual evidence thus far obtained indicates that the supposed progress made in the improvement of domesticated animals and plants is nothing more than the sorting out of pure lines and thus represents no advancement.

*Reprinted from *Science*, N. S., vol. 39 (1914), pp. 479-488.

acreage yield of fifty bushels, there would with a proper supply of plant food be a production of two hundred, two hundred and fifty or even three hundred bushels. Instead of politicians with no perspective beyond their immediate welfare—a reelection—instead of college presidents and faculties with their numerous shortcomings—according to the students and occasionally the trustees—there would be the ideal individual bred to specification and not necessarily made in Germany.

Unfortunately, variations with a perverseness incomprehensible uniformly refused to accumulate in the manner desired and at times even demonstrated their obstinacy by retrogression. It was plainly evident that there were limits imposed by nature not easily passed, and in connection with which much experimental work must be undertaken before definite progress was made and the facts fully understood.

With a realization of the difficulties involved in an attempt to apply evolution, it will be well to pause for a moment and consider certain fundamental principles before discussing the results of some of the investigations which for a time at least promised much toward the solution of the problem. Thus it may be stated that evolution in its different modifications postulates in general (1) the occurrence of numerous varying individuals, some of which are (2) eliminated by environmental stimuli leaving few or no offspring, while (3) the survivors transmit to their progeny the characters which proved of selective value, with the result that (4) through the continuation of the process the race eventually becomes adapted to surrounding conditions. The first two propositions are merely statements of fact. The real difficulties of the situation are those of ascertaining how variations which are transmitted may be recognized and produced so that the result will be a cumulative one. Until this is done breeders must continue to proceed in the same haphazard manner that they have followed for countless generations.

By selecting the largest and most perfect ears of seed corn from the variations present in the field, conversely

eliminating the remainder from reproducing, the corn grower plants with a fatuous trust in providence that a crop somewhat better or at least as good as the preceding crop will be produced. If it is a type comparatively pure the average may be maintained and the hope partially realized, but the chances for retrogression are far greater than for advancement, inasmuch as there is no means for distinguishing a variation which will be transmitted with equal or better results than in the preceding generation, from one that represents a fluctuation due to nurture and which is non-transmissible. Thus the apparently inferior ear of corn will frequently produce a yield far better than obtained from one which is perfection as graded by the methods of the "corn show," and if from the same pure race, the resultant crop will be at least as good. Artificial methods of hybridization, which furnish an immediate advancement in the succeeding generation, result in a gain which is only temporary. The increased stimulus to growth vanishes as a fluctuation.

Thus it is quite evident that there exists a problem in the evolutionary control of organisms even the partial solution of which will mark an extraordinary advancement not only for agriculture, horticulture, and animal breeding, but also for society in general.

II.

The general results of the investigations bearing upon the evolutionary control of organisms may be grouped around the principles of Mendelism, the mutation theory, and pure line breeding.

The rediscovery in 1900 of the fundamental laws governing hybridization so brilliantly established by Mendel in 1865, but unfortunately concealed in the obscure publications of the Natural History Society of Brunn, opened an extraordinary field for experimental work. This has already developed to vast proportions in connection with both the results obtained and the speculations involved, while the end is not in sight.

The investigations of Mendel, now so familiar to all biologists, and which may be mentioned somewhat in

detail here because of their bearing on mutation, consisted primarily in the crossing of tall and dwarf peas, with the result that the first filial (F_1) or hybrid generation consisted entirely of tall plants. When, however, seeds from these plants were sown the ratio of tall to dwarf plants became 3 to 1 in the second (F_2) hybrid generation, a result explained by the theory of dominant and recessive characters on the basis that there are certain determiners of unit characters in the germplasm which dominate over others during the development of the somatoplasm or body of the individual in the higher forms of life. More recently the presence and absence theory has been applied in interpreting the results. In a manner similar to the preceding when smooth yellow peas were crossed with wrinkled green peas the first hybrid generation consisted of smooth yellow forms inasmuch as the character smooth and the character yellow were dominant over the character wrinkled and the character green, and the crosses were known as dihybrids, inasmuch as they differed in respect to two characters. In the second hybrid generation the resultant ratio was 15 to 1 pure recessive, *i. e.*, wrinkled green, although the fifteen consisted of smooth yellow, smooth green, and wrinkled yellow in the proportion of 9:3:3. In the same way trihybrids have the ratio 63 to 1 pure recessive while any polyhybrid differing in " n " characters which mendelize in the usual manner will give an expected ratio of 4^n —1 to 1 pure recessive, which will become apparent only through the breeding of large numbers of individuals.

While the preceding summary represents the normal results in connection with the segregation of unit characters, studies of the past few years have demonstrated that many interesting relationships may occur between the factors governing the production of characters. For example, it has been found that two or more determiners are often present either of which will produce the given character as Nillson-Ehle demonstrated in hybrids of brown and white chaffed wheat, while on the other hand two or more determiners acting together may be necessary to bring about an effect. Such a condition exists, as

Bateson in 1910 showed, in certain white-flowered sweet peas which when crossed produce purple flowers in the first hybrid generation. The results which have led to the theory of coupling and of repulsion, particularly the latter, where the expectancy of a pure recessive may be one among many thousands, go far toward suggesting a possible explanation of many so-called mutations on the basis of ancestral individuals heterozygous for one or more characters.

Do the Mendelian principles assist us, however, in attaining the goal which we are seeking, namely the building up of an ideal organism which will continue to transmit its characters? The answer must be in the negative so far as the originating of anything new is actually concerned. Recessives may be obtained. Characters may be redistributed. They were present in the forms first utilized, however.

The mutation theory formulated by De Vries in 1901 approximately at the time interest was being awakened by the rediscovery of the hybridization principles of Mendel, needs no extended explanation to those who have been interested in evolution. Based on cultural experiments with *Oenothera lamarckiana*, one of the evening primroses, the appearance of relatively small numbers of forms which were quite distinct from the parental species and which bred true in subsequent generations, led to the inference that evolution had in many cases proceeded by discontinuous variations or mutations.

Long series of breeding experiments followed in connection with other organisms, both plants and animals, with results quite similar to those obtained by De Vries. Investigations were also made (Fischer, MacDougal, Tower, etc.) where organisms were subjected to stimuli abnormal in their nature, with the result that a modified progeny was obtained which bred true to the apparently induced character in succeeding generations. Furthermore, cytological studies (Gates, etc.) demonstrated some interesting relationships so far as differences in chromosomal composition among "mutants" were concerned.

While the evidence is far too insufficient to allow more

than a tentative opinion, there are several conclusions concerning mutation which appear justified. The nature of the results obtained through the various agencies make it quite evident that they are not all due to a single underlying principle. There are many "mutants" the origin of which is most certainly to be explained on the basis of a heterozygous condition of the gametes, and much evidence has accumulated that *O. lamarckiana* of De Vries on which the mutation theory was founded belongs to this class. Furthermore there are mutants developing in connection with the action of abnormal stimuli although it is not at all improbable that some of these result from heterozygotes. It may be mentioned that Humbert (1911) in experiments with 7,500 pure line plants of *Silene noctiflora*, one of the "pinks" utilizing methods similar to those of MacDougal, failed to obtain any "mutants." Another explanation of the results in connection with the influence of abnormal stimuli is that the modification takes place through the destruction of a factor and thus the process is one of subtraction instead of addition. There are also investigations, notably those of Gates, in which the aberrant organism apparently results from the abnormal behavior of the chromosomes at some stage during the life cycle. *Oenothera gigas* with its tetraploid chromosomes is here of much interest.

Notwithstanding these diverse results, there is little indication that anything actually new has been added to the organism which would not have occurred within a pure line. If this is true the heterogeneous school of mutationists can be of little assistance beyond suggesting the way in which evolution did not take place.

The experiments on the basis of pure line breeding belong to a comparatively recent period and are of the utmost importance. Johannsen in 1903 published results based on a pure line of beans self-fertilized for successive generations and evidently homozygous. From a bean weighing 95 centigrams and far above the average in size he obtained plants producing beans varying in weight from approximately 35 to 70 centigrams, but all far below the weight of the parent. Utilizing these in turn as

parental forms, from those having a weight of 35-40 centigrams there resulted a progeny with an average of 57.2 centigrams, while from those having a weight of 65-70 centigrams a progeny was obtained which had an average of 55.5 centigrams. In other words, selection had not only failed to make any advancement, but actually resulted in a slight retrogression. Facts quite in accord with this but giving much more pronounced results have been obtained by Tower (1906), Jennings (1908), Johannsen (1909) and others. It should be noted, however, that there have been several experiments, notably those of De Vries with buttercups, Tower with potato beetles, and Smith with Indian corn, where a possible advance of a character was recorded in a group. Heterozygotes here may have been responsible for the result, although again the explanation may consist in the elimination of the effects of a determiner.

The results in mixed races as exemplified by corn, beans, etc., where selection has gradually improved a group of organisms but finally reached a limit beyond which no progress appeared possible, are comparatively well understood and are due, as explained by Shull (1908), to the separation of the pure lines which were present in the race at the beginning. This is where the average agriculturist, horticulturist, and animal breeder has gone far astray and, having succeeded for a few generations in making progress, has failed to understand why he may not continue to be successful.

Thus we find that attempts to modify a character by selection within pure lines within a small number of generations have almost universally failed, and that the few apparent results to the contrary must be looked upon with the suspicion that the population was a mixed race and that Mendelian principles applied.

Once again we are led to propound with still greater emphasis the question, "How then has evolution taken place?" "In what manner have organisms acquired their characters?" "Is it possible to escape the difficulties that confront the investigator on every side?"

III.

The application of statistical methods to problems of biology has provided and will continue to provide facts of decided value obtainable in no other way. Nevertheless, the use of data "en masse" uncoordinated with experimental methods can not solve the riddle of existence so easily as some, at an earlier period at least, would have had us believe. There are, however, investigations which seem fundamental to the problem under discussion and which may well be approached from the statistical side. These relate to the influence of certain factors composing the environment as well as to the part played by asexual and sexual reproduction, corresponding in reality to close and cross breeding, upon variability and size in organisms.

Some studies undertaken in 1900 in connection with the influence of food supply on variability¹ based upon the comparison of groups of *Chrysanthemum leucanthemum* L., the common white daisy, as well as *Perca flavescens* Mitch., the yellow perch, indicated that the difference in variability as evinced by the coefficient of variation for a group with a maximum food supply as compared with a group having a minimum food supply, was extremely small and well within the limits allowed by the probable error. From this the inference was that external stimuli played an extremely unimportant part under normal conditions as a cause producing variability in general.

Attempts were subsequently made to obtain data bearing on the results of close breeding and cross breeding which differ merely in degree from parthenogenesis and amphimixis. The question is an important one, for if cross breeding is only valuable in sorting out and combining existing characters, it not only obscures the facts, a knowledge of which is necessary before progress can be made in building up new characters, but results in no actual advancement in cumulative evolution. Here the material for study consisted of scalariform or cross-bred and lateral or close-bred (parthenogenetic) zygospores—

¹Science, p. 728, 1907.

in reality the young individuals—of the common filamentous green alga *Spirogyra inflata* (Vauch). Upon applying statistical methods the close-bred zygospores were found to be 23 per cent more variable¹ in size as well as larger, both in length and actual volume, than the cross-bred zygospores. The results were not in accord with the general belief that cross breeding increased variability, although studies by Warren, Kellogg, Casteel and Phillips had pointed out that this belief was not substantiated by facts, which, however, did not actually warrant the idea that variability was decreased in cross-bred forms. The studies on the zygospores also suggested that sex existed primarily for the purpose of limiting variability, a hypothesis proposed on purely theoretical grounds by Hatschek in 1887. Another conclusion which followed from the same investigation was that in connection with the origin of death² and which may be mentioned here. This is summarized by stating that death apparently occurs as the result of the continually forming body cells becoming so variable through absence of control by amphimixis, that eventually some one group of functional importance fails to meet the limits imposed by the environment. In consequence of this the group, together with the remainder of the colony—the individual—perishes.

In connection with the difference in the variability of close-bred and cross-bred zygospores it seems quite evident that the result is brought about by some factor other than the environmental stimuli which are assumed to produce fluctuation, inasmuch as the material was homogeneous in every respect with the exception of the manner of reproduction. The question is a difficult one, however, not to be settled by a single investigation giving positive results, and because of its importance should receive attention.

In reference to those who hold to the belief that cross breeding, conjugation and amphimixis—the three terms differ merely in degree—increase variability, it may be well to inquire concerning some of the evidence which has been instrumental in formulating the opinion. Without

¹Science, p. 907, 1908.

²Science, p. 935, 1912.

any desire to be critical and at some risk of exceeding the controversial bounds which a paper of this nature allows, a few of the more important investigations touching upon the subject will be considered.

Castle, Carpenter, Clark, Mast and Barrows (1906) in a series of observations as to the effect of cross breeding and close breeding on the variability and fertility of the small fruit fly, *Drosophila ampelophila* Loew., stated that "inbreeding did not affect the variability in the number of teeth on the sex comb of the male, nor the variability in size," basing the opinion on the coefficient of variation in the number of spines and the standard deviation in the length of the tibia. In the former case the data certainly do not permit a clear conclusion one way or the other, but the value of the character which represents the sum of the teeth of the sex combs of the right and left proximal tarsal segment, where there is undoubtedly correlation, may be open to objection under any consideration. If, however, from the data presented in the study the value of the coefficient of variation is computed, which, strange to say, was not done in the paper, and thus allowance made for the greater length of tibia in the cross-bred forms, the combined inbred forms exhibit a variability relatively 68 per cent greater than the cross-bred forms.

Jennings (1911) in summarizing breeding experiments with *Paramecium* concluded that "The progeny of conjugants are more variable in size and in certain other respects than the progeny of the equivalent non-conjugants," and farther, "Thus conjugation increases variation." Continuing the investigations, he subsequently stated (1913) that conjugation increased the variation in the rate of reproduction. While the careful methods used by Jennings have brought to light many interesting and valuable facts, it is evident, from a critical consideration of the data, that they by no means allow such conclusions.

So far as size is concerned in a pure race, non-conjugants and their progeny were more variable than conjugants and their progeny, as noted in Table No. 28. In a wild race the progeny of the conjugants were slightly more variable than the progeny of the non-conjugants, as

illustrated in Table No. 32, although in two of the nine generations tabulated the variability was greater in the case of the non-conjugants. So far as the rate of fission is concerned, the evidence is unmistakable that the conjugants were more variable. There is, however, a comparatively simple explanation for this when the statement is noted that the number of abnormal individuals, as well as the mortality, was greatest among the progeny of the conjugants. With a considerable number of forms thus having a lower rate of fission, one could expect nothing except a greater variability in the rate of fission. This becomes the more evident when it is found that the higher variability of the conjugants was caused by the considerable number with the low rate of fission.

Considering the data obtained in the breeding of plant forms where the assumption has long been prevalent that hybridization increases variability, it is found that the variability of the F_2 generation as compared with the F_1 generation or a single parental generation may be increased, but that the actual variability as a whole is not increased when the united parental types are taken into account. This may be illustrated by utilizing data from an interesting paper by Hayes (1912) dealing with correlation and inheritance in tobacco. Here, calculating the constants for two parental types combined (401 and 403) in respect to number of leaves and height of plant, it is found that the coefficient of variation has decidedly decreased through the hybridization, although the number of combinations have increased.

There exists the possibility, however, that variability will appear to be increased when forms having the same phenotype but different genotypes are bred together. Such a condition may be illustrated by the two white strains of sweet peas crossed by Bateson which produced purple flowers in the first (F_1) hybrid generation, and purple, pink, mixed, and white flowers in the second (F_2) hybrid generation. New combinations occur, but there is no evidence of increase in unit characters, nor is there an actual increase in variability.

Turning for a moment to size characters, the influence

of cross breeding or conjugation is of decided interest inasmuch as facts bearing on the solution of the problem as to how size may be increased to the physiological limit, even though the results hold for a single generation, have the greatest practical value for the future of agriculture and animal breeding.

It should first be noted that size in a unicellular organism is dependent on the absolute size of the individual cell with a limit undoubtedly imposed by laws governing the ratio between volume and surface in connection with osmosis. In multicellular organisms, however, size characters may depend upon either the size or the number of the component cells or upon both factors. This distinction possibly explains an apparent diversity in results obtained in the two groups.

Darwin, Mendel and others who have seriously considered the question have recognized that hybrids, among plant forms in particular, usually grew to a larger size than either parental form, a result probably due to the increased rapidity of cell division and consequently greater number of cells as conjectured by East. In the study of zygospores of *Spirogyra* it was therefore noticed with some interest that the cross-bred forms were smaller than the close-bred forms so far as both length and volume were concerned. Jennings (1911) in his study of *Paramecium* reached a contrary conclusion, stating that "The progeny of conjugants . . . were a little larger than the progeny of non-conjugants and the difference appears to be significant." This is correct merely in reference to length, however, and that it is not true for actual size as indicated by volume is evident on applying the formula for the volume of a prolate spheroid ($V=1/6\pi l d^2$) by which it may be demonstrated that the non-conjugant forms, while smaller than the others at the beginning of the experiment, actually became larger. Thus in agreement with the zygospores of *Spirogyra*, conjugation decreased size.

The question immediately occurs as to the cause of the increased size and vigor among cross-bred multicellular organisms when the evidence indicates that cross-bred

unicellular forms are smaller instead of larger. Some investigations that I have undertaken indicate an answer apparently meeting the conditions. While sufficient control experiments have not been made to venture more than a provisional opinion, the data suggest that the cells of cross-bred multicellular organisms are actually smaller than the cells of inbred or pure line forms, and that the more rapid division is a function of the greater ratio surface has to volume in a small cell with the better opportunity thus obtained for increased metabolism.

That there is need of further investigation on size and variability in pure lines and in cross-bred forms through the application of statistical methods in connection with the maintenance of pedigrees through long series of generations seems evident. Eventually theories will make way for facts which will allow a proper perspective.

IV.

Where do the results presented in the preceding pages lead us? Does their value, so far as their bearing upon the production of new and transmissible characters that will build up an organism in a required direction, consist merely in the formulating of hypothesis after hypothesis which as investigations proceed will in turn make way for other hypotheses equally transient? Or, on the other hand, do they mark a definite progress along the lines we are endeavoring to follow, namely, the control of evolution.

Before attempting a reply which must prove more or less unsatisfactory to those looking forward to immediate results, it seems advisable to pause for a moment and in the light of the preceding discussion consider the types of differences—variations—which exist in so far as they may effect the result with which we are chiefly concerned.

Beginning at an early period in the history of evolution with the idea that all variations might be inherited, results soon suggested that the characters due solely to surrounding influences such as food supply, etc., were not thus transmitted. These were called *fluctuating varia-*

tions. On the other hand, variations due to the structural changes in the germ cells which were passed on from one generation to another have been spoken of as *inherited variations*.

The evidence at present indicates that farther subdivisions must be made and that normal inherited variations consist of two quite distinct classes. The variations where the results are due to the interaction of factors in accordance with Mendelian principle, and which, adapting a term used by Plate (1913), may be called *amphimutations* inasmuch as the condition is due to the mingling of two lines of descent, the other variations, as a class, in which the results—evolution in the abstract—are due to a series of units added as increments, may well be called *cumulations*. It is quite evident that the term "mutation" can not continue to include both types. As a coordinate term fluctuating variations may be spoken of as *fluctuations*.

Under abnormal variations must be classified forms ranging from monstrosities to slight departures from the ordinary condition, some of which are undoubtedly due to the losses or modifications of unit characters through the action of extraordinary stimuli, while others may be due to abnormal and unequal distribution of chromosomes occurring at the time of their division. The *idiomutations* of Plate are here included.

The answer to the question as to the progress made in the application of evolution to the creation of new forms rests in the statement that the attack on the problem is becoming more concentrated. The selection of fluctuations has been tried and has failed. Efforts by means of amphimutations end in a maze of circles with no evident progress. *Idiomutations*, so far as one may judge from the evidence, present retrogression rather than advancement. It is by means of pure lines under normal conditions that one may search with advantage for cumulations, the units by which to build the new. There the evidence will be unobscured either by the pyrotechnics of Mendelian formulæ, or by the factitiousness of abnormal stimuli. Fluctuations will be present, but statistical methods will

permit their evaluation. Should the measurement of the mean in the tenth or even the one hundredth generation present no advancement, failure is not necessarily implied. Nature has devoted fifty millions of years or more to her work. There should be no discouragement if a few paltry years of investigation fail in duplicating her methods.

It is with a feeling not unmixed with pessimism, however, that one views the conditions under which work of the character outlined must evidently go forward. Those engaged in teaching have with a few exceptions time for little more than an occasional investigation of limited scope, particularly in a field which requires continuous application. Governmental departments where it could best be taken to a successful issue have only too often been subservient to political policies which demand immediate results. An ounce of compiled compendium is—to them—worth more than a ton of painstaking investigations which makes an advance on a theory. Looking a few generations into the future is not their concern.¹ A remedy for such conditions clearly lies in endowments either in connection with universities, or through the establishment of the specialized private institution.

That the problem of applied evolution will eventually be solved there can be no doubt. That it will occur in our generation may only be expressed as a hope.

¹Exceptional work has been done by those more or less closely connected with certain State Agricultural Experiment Stations. The names of East and Hayes, of Connecticut, Pearl, of Maine, Emerson, of Nebraska, Dean Davenport, Rietz and Smith, of Illinois, are familiar to all interested in the application of the principles of evolution. One often conjectures, however, as to the extent to which some of the most valuable contributions are in reality "by-products" of investigations meeting the approval of the "Missouri" type of legislator.

CELL DIVISION AND THE FORMATION OF PARAMYLON IN *EUGLENA OXYURIS* SCHMARDA*

The method of reproduction in *Euglena oxyuris* Schmarda has not been observed, while the characteristic manner and the time element involved in the formation of the constituent parts of the cell is also of some interest. Therefore, the following notes made in connection with some uncompleted studies on the life cycle of *Euglena* are presented.

Of the forty or more species constituting the genus, *E. oxyuris* Schmarda is by far the largest, often attaining a length of approximately 500 μ . In the study mentioned, several of the smaller species of *Euglena* had been observed by the writer, to encyst and after repeated divisions pass through an apparent sexual stage, in consequence of which it was desirable to check the results with a larger form, permanent preparations of which could be more easily made. Therefore, several specimens of *E. oxyuris* were transferred from a culture to a lens paper aquarium, the margins of which were closed by paraffin oil to prevent evaporation and placed under observation, Feb. 4, 1906. No reproductive processes similar to those in the smaller species mentioned were observed, but several in the process of division were noted and studied with the 1-12 immersion objective. The characteristic organs of the species are the oval nucleus, the large anterior and posterior paramylon granules, the stigma, reservoir, pharynx and chloroleucites. The figures are all based on camera lucida drawings.

On Feb. 6, at 10:03 A. M., a single individual was observed much broader anteriorly than the normal form and in which the nucleus had approached the stigma while the anterior paramylon granule occupied very

*Reprinted from *The Ohio Naturalist*, vol. 15 (1915), pp. 449-451.

nearly the normal position of the nucleus. It was not until 1:45 P. M. that the division of the stigma was observed, the nucleus in the meantime having become obliquely elongated, and the anterior paramylon granule having moved down to a position beside the posterior granule. At 3:35 P. M. division had so far progressed that the anterior fourth of the individual—individuals?—were separated, the two nuclei being almost distinct. At 4:15 P. M. longitudinal division was nearly complete and the two nuclei were moving slowly posteriorly to their normal position. At the same time a peculiar phenomenon was taking place in connection with the two paramylon granules. The protoplasm containing the granule of the individual on the left would rapidly flow posteriorly, so that the granule was actually in the posterior end of the individual on the right as indicated by the solid arrow. The time consumed was 20 seconds. Then the reverse flow occurred and the protoplasm containing the granule of the individual on the right would flow to the left as indicated by the dotted arrow. It would seem at times as if an observer could scarcely refrain from concern as to the probability that one individual would inherit all the paramylon. At 4:25 P. M. the process of division was completed, the nuclei having moved posteriorly and the individuals appearing normal in every way with the exception that each lacked the large anterior paramylon granule. Observations were made periodically the following day with the expectation of noting the development of the new granule. It was, however, not until the succeeding day at 9:00 A. M., approximately 40 hours from the time of the complete division that an irregular, but distinct granule became visible. This gradually increased in size, but had not attained its full development at the end of the day, when the observations were brought to a close. The other twin individual had in the meantime disappeared.

There are two factors, however, which may have been instrumental in delaying the formation of the anterior granule, the lowering of the room temperature nearly to freezing at night, and the possible lack of the necessary

nutrient material in the small closed lens paper aquarium.

While the synthesis of "paramylon," a term first suggested by Gottlieb, (1851) because of the similarity in chemical composition to amylon (starch), normally occurs in connection with the chloroleucites present in the Euglenidae, the question as to its possible free formation as an assimilation product of the protoplasm has long been one of interest and one concerning which no definite statement may up to the present time be made. The mode of formation of the anterior paramylon granule in *Euglena oxyuris* is extremely suggestive, however, that the result is due to the activities of the protoplasm quite independently of the numerous small chloroleucites present. Distributed irregularly as they are throughout the cell body, it seems difficult to believe that their products should unite to make a structure so definite in form and position.

The time taken for the division of the individual was $6\frac{1}{2}$ hours, with the assumption that the condition as figured in "B" had occupied only a brief period. Keuten (1895) notes the time of division in *Euglena viridis* as 3-4 hours. There are apparently no notes concerning the time necessary for division among other related forms, although Doflein (1911) gives a comparative table for various species of Protozoa. The factor is undoubtedly a variable one and largely dependent on the surrounding conditions particularly temperature and nourishment.

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A LAND PLANARIAN WITH AN ABNORMAL NUMBER OF EYES*

The land planarians which are relatively common in the tropical regions have few representatives in the temperate zones, only two species thus far being known from America north of Mexico, with the exception of the introduced form, *Placocephalus kewense* (Moseley) occurring in the hot houses. These are *Rhynchodemus sylvaticus* (Leidy) and *Rhynchodemus atrocyaneus* Walton, the latter represented by only two specimens and the former by ten specimens all belonging to the collection of the Department of Biology, Kenyon College. It is therefore of interest to record a specimen belonging to the former species which possesses two pairs of eyes instead of the normal single pair. The individual was among five collected July 4, 1904, under the partially decayed stem of a Virginia Creeper — *Ampelopsis quinquefolia*, and the peculiarity was not noted until sometime later when cleared in cedar oil preparatory to sectioning.

The two pairs of eyes are nearly normal in position, the anterior pair being 0.26 mm. and the posterior pair 0.33 mm. from the tip of the head in the preserved specimen fixed in hot sublimate alcohol (Apathy) and somewhat contracted. The anterior pair is nearly twice the diameter of the others. No peculiarities of this nature have thus far been noted among land planarians although vonGraff ('99) in his monograph briefly discusses certain variations in other organs.

It is of interest to extend the range of our land planarians and those engaged in work in Invertebrate Zoology should be able to find them, particularly on summer mornings after a rain, under partially decayed boards on lawns, in orchards, etc., in company with young snails which they superficially resemble.

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R. sylvaticus was collected by Leidy in 1851-58 and the material evidently lost. Since then the writer has taken it at Gambier and Urbana, O., and at Meadville, Pa. It is about 10 mm. long, grayish black with two darker longitudinal lines dorsally. *R. atrocyaneus* is about 20 mm. long when in a living condition, and uniformly dark blue in color. It has only been found in Gambier, O. When collected, specimens should be killed almost immediately with some hot "killing fluid" inasmuch as they die and disintegrate very quickly. They may, however, be kept alive for several hours in a small clean vial provided there is also placed within a piece of a partially decayed leaf.

VARIABILITY AND AMPHIMIXIS*

A COMPARATIVE STUDY OF THE VARIABILITY IN ZYGOSPORES OF *Spirogyra inflata* (VAUCH.) FORMED BY LATERAL (CLOSE BREEDING) AND BY SCALARIFORM (CROSS BREEDING) CONJUGATION, AND ITS BEARING ON THE THEORY OF AMPHIMIXIS AND CORRELATED PROBLEMS.

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I. PRELIMINARY OUTLINE

1. *Introduction*

Comparative studies along statistical lines of the results produced by cross breeding and close breeding afford data of value bearing on the problem of evolution as well as the subsidiary problem of the origin of amphimixis. It has long been assumed (Weismann, '76) that sex existed primarily to increase variability and with the further assumption that the variations thus produced were heritable and accumulated, the differentiation of organisms was logically explained. As a corollary to such a conclusion the belief has long been prevalent that the offspring of

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organisms produced by cross breeding were as a group more variable than those produced by close breeding, an idea which gained further acceptance in connection with the investigations of Castle ('06), Jennings ('08, '09, '12, '13) and others interested in problems of genetics. That there was excellent evidence for exactly an opposite view and that an analysis of the results presented by the investigators mentioned above did not bear out the conclusion that variability was increased by cross breeding has been pointed out by the writer (Walton, '08, '12, '14) in some earlier papers.

The importance of arriving at a correct conclusion concerning the part played by hybridization and cross breeding in evolution can not be overestimated. If units are merely redistributed and form characters resulting in no actual evolutionary progress, work along Mendelian lines tends rather to obscure the facts of value toward solving the problem of the origin of species as well as that of evolutionary control in animal and plant breeding. It is therefore well to obtain data from as many sources as possible bearing on the question.

Among the species of *Spirogyra*, a group of algæ belonging to the class Conjugatæ, there are several which reproduce both by lateral conjugation where the adjacent cells of a single filament unite to form the zygospore, itself a young individual, and at the same time by scalariform conjugation where the cells of two distinct filaments unite to form the zygospore. Thus there is an example of a population producing under the same environment two groups of individuals, one by close breeding (lateral conjugation) and the other by cross breeding (scalariform conjugation), and a comparison of the variability by statistical methods should afford evidence toward the solution of the problem presented where the offspring have arisen from a common ancestor as indicated in the material studied.

2. Historical

Much has been published concerning hybridization, cross and close breeding, amphimixis and parthenogenesis, all of which are distinguishable from one another

merely by degree, nevertheless so far as the subject under discussion is concerned, the conclusions in general have largely been assumptions based on little or no evidence.

It was Weismann ('76) who was evidently the first to definitely express the importance of sex in producing variations, an idea to which he consistently held in his subsequent papers, while Nägeli ('84), Strasburger ('84), Hatscheck ('87), Haycraft ('95), etc., believed likewise on theoretical grounds that variability was reduced by amphimixis.

The first paper presenting tangible evidence upon the subject was that of Warren ('99) who found that parthenogenetically produced *Daphnia magna* were slightly more variable as measured by the "Standard Deviation" which had a value of 2.95, than the mothers whose "Standard Deviation" was 2.22. The small number utilized, 96 in the first instance and 23 in the second instance, together with the fact that the mothers represented a selected class, only those *Daphnia* producing young being included, did not allow placing much reliance in the results. Warren ('02) compared 60 parental aphids (*Hyalopecterus trirbodus*) and their 368 offspring as well as a series from 30 aphid grandparents and their 291 grandchildren. The variability was found in a comparison of grandparents and grandchildren (parthenogenetic) to have slightly decreased in respect to frontal breadth and considerably increased in respect to length of right antenna, but again objections similar to those in the preceding paper render the conclusion of little value, as Warren himself observed.

Casteel and Phillips ('03) measured drones and workers of *Apis mellifica*, the honey bee, selecting individuals at random from different colonies, and tabulating classes and frequencies without, however, a further application of biometrical methods. The "range of variability" was found to be greater in the drones than in the workers. Lutz ('04) criticized the methods utilized in the paper, nevertheless variation as measured by the standard deviation upon calculation by Wright, Lee and Pearson ('07) was found greater in the drones by a difference ranging

from 0.22 to 2.63 in respect to all five characters studied in the single group of 50 Italian workers and 50 drones of real value for comparative purposes.

Kellogg ('06), in a preliminary paper dealing with drones and workers of bees and also with female aphids, concluded that not only was there no evidence that amphimixis produced increased variability, but that it was an unnecessary factor in the production of Darwinian variation. The results were summarized as follows:

(a) In all but one of the characteristics studied, the amount of variation both quantitative and qualitative, is markedly larger among the drone bees than among the workers, and in the one exceptional characteristic it is no less; (b) no more variation in wing characters is apparent among drones or workers that have not been exposed in imaginal condition to the rigors of personal selection than exists among bees, drones or workers, that have been so exposed; (c) the variation in wing characters in drone bees reared in worker cells is no greater than that among individuals reared among drone cells; (d) the variation among drones hatched from worker laid eggs is markedly larger than that among drones hatched from queen laid eggs

Eleven "lots" were studied with a small number (No. 3, 48; No. 7, 54; No. 8, 75; No. 9, 26; No. 11, 60) in many of the "lots." Even though the probable errors would have been large and while the material was heterogeneous, the facts brought out are of extreme interest, particularly when considered with the results obtained by Casteel and Phillips ('03).

Wright, Lee and Pearson ('07) made a comparative biometrical study of 129 queens, 130 drones, and 129 workers taken from a nest of the common wasp *Vespa vulgaris* in Charterhouse, England. In connection with the wing dimensions, the coefficient of variation was found to be greatest in the worker, less in the drone, and least in the queen, differing from the bee as noted above where drones were more variable than workers. The conclusion here of interest was:

There is no evidence in favor of parthenogenesis resulting in a smaller variability than sexual reproduction, for if the workers be more, the queens are less, variable than the drones.

It was suggested by the writers that the large variabilities of the workers might have resulted from subclasses among them due to differentiated functions or natures.

Castle, Carpenter, Clark, Mast and Barrows ('06) made observations on the variability and fertility of *Drosophila ampelophila* Loew, the small fruit fly, as modified by inbreeding and cross breeding. They found that "inbreeding does not affect the variability in number of teeth on the sex comb of the male, nor the variability in size." While the conclusion is not in accord with an earlier observation (p. 780) that variability would seem to have been increased by inbreeding so far as a comparison of the sixth inbred generation with the sixty-first generation, the small number utilized in the sixth generation (40 males in series A-6, B-6, C-6 each) was ground for the opinion that such a conclusion had little value in comparison with data pointing in the reverse direction. If however we calculate the coefficient of variation for the length of the tibia, an unfortunate omission on the part of the writers, it may be noted that the flies produced by inbreeding are decidedly more variable than those produced by cross breeding. Data for this conclusion are given in a subsequent part of the present paper.

Walton ('08) noted that the results of measuring zygospores of *Spirogyra* indicated that the close-bred individuals were more variable than the cross-bred individuals and furthermore that the data went far toward confirming the theory that sex existed for the purpose of limiting instead of augmenting variability.

Emerson ('10) found that crosses between races of plants (maize, squash, beans, gourds) differing in size and shape had the variability of the second (F_2) generation approximately twice as great as the variability of either parental form or of the first (F_1) generation. This he explained on the basis of the segregation of size and shape characters. Similar results were obtained by East ('11) for maize and Hayes ('12) for tobacco.

Jennings ('11) extending and summarizing his breeding experiments on *Paramecium* concluded that The progeny of conjugants are more variable, in size and in certain other respects, than the progeny of the equivalent non-conjugants. Thus conjugation increases variation.

Later ('13) continuing his investigations he stated that conjugation increased the variability in the rate of repro-

duction. In a subsequent part of the present paper a somewhat critical review of the data and conclusions therein noted is presented.

3. *Material*

In obtaining material early one April for the laboratory work of a class in biology, the collection being made in a small pool resulting from the overflow of a rivulet, a peculiar species of *Spirogyra* was noticed in which both lateral and scalariform conjugation was taking place often in the same filament. It was at once suggestive that a comparison of the variability in the two groups of zygospores would present facts of interest in connection with the effect of close breeding and cross breeding on variability as well as affording evidence as to the theories of amphimixis.

The species was first determined as *Spirogyra quadrata* (Hass.) but subsequent examination indicated that it should be classified as *Spirogyra inflata* (Vauch.).

The material utilized for the measurements was all procured at one time from a restricted area one or two inches square on the surface of the pool and included only the one form of *Spirogyra*, that alone being present as a mass 3 or 4 inches in diameter. Inasmuch as both lateral and scalariform conjugation occasionally took place in the same filament a suggestion that two species were represented can not be made for the filaments are alike in every characteristic. Of the 500 zygospores observed 45 per cent were produced by lateral conjugation.

4. *Methods*

In considering the variability of large numbers of microscopic forms, rapid and accurate measurements are a necessity. Pearl and Dunbar ('03) in measuring *Arceella* used a camera lucida, marking the dimensions by means of a needle point, and reducing to microns. Pearl ('06) adopted a similar method for *Chilomonas*, using a magnification of 689.7. Pearl ('07) in measuring *Paramecium* used a 2/3-inch objective and a No. 1 ocular. By means of a camera lucida the points to be measured were

projected on cards, marked, and measured with a vernier calipers to tenths of millimeters. Multiplying the measurements so obtained by the proper reduction factor found by calibrating with a stage micrometer, they were reduced to microns and recorded. Jennings ('11) at first measured *Paramecium* from a slide with an ocular micrometer. Later an Edinger drawing and projection apparatus was used, the projected images of the specimens on a slide in a flat drop of 25 per cent glycerine, without a cover glass which by pressure would have caused distortion, were enlarged to 500 diameters and measured with a milimeter ruler.

In the present study, the material was preserved in 2 per cent formalin, the first series of measurements¹ being made April 2, while measurements of 358 were completed before May 16, and the remaining 42 finished Aug. 21 of the same year. Swelling of the zygospores did not occur to an appreciable extent, a possible error considered in a subsequent part of the paper. Using a B. and L. BB-6 microscope with a No. 1 ocular and a 1/12 oil immersion, a slide with a couple of drops of fluid containing the material was covered with a No. 2 coverglass, the superfluous liquid drawn off by means of a pipette, and the preparation placed on the mechanical stage. Beginning at the lower right-hand corner the slide was moved from left to right and each zygospore presented in the field in a uniformly horizontal condition, was measured. On reaching the left margin of the preparation, the slide was returned to the first position, moved sufficiently toward the observer so that a new path would be traversed, and the operation repeated. Thus the selection was at random and no zygospore measured twice. The dimensions were marked on note paper by means of a camera lucida at a magnification of 1,460 diameters, the two cross lines representing length (x) and diameter (y) having at the point of juncture an "S" or an "L" for scalariform or lateral conjugation. Only those zygospores having definitely formed membranes were considered.

In the reduction of data, so soon as the projections of

¹I am indebted to Dr. C. C. W. Judd, of Baltimore, Md., at that time a senior in Kenyon College, for work in part in obtaining the first series of measurements.

the apparent dimensions were completed, the length of the lines x and y were measured with proportional dividers (Keuffel and Esser No. 441 special) adjusted at the ratio 1,460 to 1,000, thus giving a reading in tenths of microns. Accurate adjustment was made possible by means of a micrometer screw, on the basis of the equation for similar triangles;

$$1,460 \text{ mm.} : 1,000 \text{ mm.} = 160 \text{ mm.} - x \text{ mm.} : x \text{ mm.}$$

where 160 represented the total length of the dividers, and x or 65.04 mm. the point of adjustment. Having checked the adjustment, it only became necessary to note the size of a given zygospore with the longer legs of the instrument, then by applying the shorter legs to a millimeter scale, to read the result. The various constants were then computed on the basis of the work of Pearson and of Elderton by means of a Brunsviga calculating machine. I am indebted to Dr. H. H. Mitchell of the University of Illinois for checking the mathematical data.

II. CONSIDERATION OF RESULTS

The direct results obtained by the statistical methods employed are here presented. These furnish the basis for the general discussion and conclusions which follow. The problems of biology relating to evolution need the application of statistical methods to studies in genetics. In no other way will it be possible to clearly demonstrate the relative efficiency of the different types of variation—fluctuation, amphimutation, cumulation, etc.—in originating and maintaining the diverse forms of life that exist. Similarly the importance or unimportance of small variations in animal and plant breeding may only thus be explained. The refinements of curve fitting are by no means necessary, nevertheless values are thus exhibited which are presentable in no other way.

1. *Comparative Variability in Length of Zygospores*

In the frequency distribution for lengths of the two groups of zygospores the class range adopted was two microns as compared with a range of one micron in the

distribution of diameters. The more extended as well as the more irregular distribution of lengths of the lateral zygosporos when compared with the scalariform zygosporos is at once suggestive that the group thus close bred, is the more variable one. It is also of some interest to note that the empirical range of variation for the laterally formed zygosporos,—with length from 49 m. to 83 m.,—is considerably greater than in the scalariform zygosporos with lengths from 47 m. to 79 m. While this is not a measure of statistical variability, it undoubtedly has a genetic value.

The general constants for the variability in the length of the zygosporos of the two groups are shown below. It may be noted that the mean (M.) or average length of the zygosporos produced by lateral conjugation exceeds the mean of the scalariform conjugants by 1.94 microns, while the probable error for the first constant is $\pm .1776$ and for the second constant $\pm .1345$. The difference is therefore a significant one so far as the present material is concerned.

It is in the comparison of the standard deviations (σ) and the coefficients of variation (C. V.) that the results of most interest appear, however. The former constant in lateral conjugation has a value of 1.6986 in excess of the same constant in scalariform conjugation, or relatively 29 per cent. This is more than thirteen times the probable error. In the coefficient of variation, an abstract number permitting comparison with similar constants in other organisms, the results indicate that the variability in lateral conjugation exceeds that occurring in scalariform conjugation by 2.4271 or relatively 26 per cent, a result corroborated by the distribution of the diameters. The probable errors are sufficiently small in comparison with the differences noted, that they may be considered negligible.

Skewness is negative in the curve for lateral conjugation, the mean being on the left side of the mode, but its value is less than the probable error. In the curve for scalariform conjugation skewness is positive with a value slightly more than three times the probable error. There-

fore the differences of the two constants appear to have no particular value so far as the present material is concerned.

The analytical constants necessary for the fitting of the curves indicate that type IV curves may be used for each method of conjugation. In lateral conjugation the equation is

$$y=10.842 \left(1 + \frac{x^2}{29.2687^2} \right)^{-33.6912} \times e^{-9.5995 \tan^{-1}(x/29.2687)}$$

and in scalariform conjugation similarly the equation is

$$y=5.0014 \left(1 + \frac{x^2}{529} \right)^{-11.6945} \times e^{-8.9389 \tan^{-1}(x/11.50)}$$

while the frequency polygons and the fitted curves illustrate the conditions diagrammatically.

2. *Comparative Variability in the Diameter of the Zygosporcs*

The class range adopted in the frequency distribution for diameters of the two groups of zygosporcs was one micron, measurement being made at the maximum diameter. An inspection of the distribution shows at once the greater concentration of the variates in scalariform conjugation, and thus their smaller variability. In considering the general constants of variability based on the diameters it is to be noted that the means (M.) do not differ, as we found when considering length. The standard deviation (σ) and the coefficient of variation (C. V.) once more demonstrate the greater variability of the laterally formed zygosporcs. The values of the constants for skewness (Sk.) are not sufficient, however, when considered with the probable error², to be of importance. The frequency polygons illustrate conditions, although no curves have been fitted.

²The following formulae as the basis of the probable errors, may be noted:

$$PE\sigma = .67449 \sqrt{\frac{M_4 - M_2^2}{4M_2}} / n, \quad PE_{C.V.} = \frac{.67449}{\sqrt{2n}} \left[1 + 2 \left(\frac{v}{100} \right)^2 \right]^{\frac{1}{2}},$$

$$PE_{Sk.} = .67449 \sqrt{\frac{3}{2n}} / \sqrt{1 + 3(Sk.)^2}.$$

3. *Comparative Correlation of Length and Diameter*

In view of the results obtained in a consideration of the variability, it will be of some interest to ascertain whether the inbred zygosporcs produced by lateral conjugation will be more or less correlated than the cross bred zygosporcs produced by scalariform conjugation so far as length and diameter are concerned.

The value of perfect correlation as measured by the constant (r) is unity, while absence of correlation allows the value to become zero. Length is taken as the subject class (y) and diameter (x) as the relative class in the accompanying tables.

While one might infer that the longer a zygosporc the greater the diameter, such a condition is not apparent by mere inspection of the tables in either case. Consequently on solving the equations we are prepared to find that the coefficients have an extremely low value in each group.

Lateral Conjugation	$r = .1894 \pm .0460$
Scalariform Conjugation	$r = .0934 \pm .0473$

Although in lateral conjugation the value is more than four times the probable error, one is scarcely prepared to state that there is greater correlation between characters in close breeding than in cross breeding on the basis of the data noted above. When considered with the results presented in Table XII, the conclusion seems fully established, however.

4. *Comparative Size of Zygosporcs*

The term "size" as noted in the subsequent discussion is open to various interpretations dependent as to whether length, diameter or volume is being considered, a condition which to some extent complicates the interpretation of size characters among multicellular organisms which are in general dependent on the number rather than the dimensions of the component cells.

Those zygosporcs produced by lateral conjugation (close bred), so far as the present material is concerned, have an average length considerably exceeding those produced by scalariform conjugation (cross bred) while

the diameter is approximately the same. This is illustrated in Table VIII.

Consequently, here, the average zygospore produced by lateral conjugation has a greater volume than that produced by scalariform conjugation. Utilizing the formula for computing the volume of a prolate spheroid ($V = 1/6\pi ld^2$) the difference is 771 cubic m. in favor of the former, although relatively this approximates only 3 per cent.

A question of some interest is at once suggested, namely, the possibilities for nourishment and development in cells of large and of small volume, inasmuch as one with a maximum volume has relatively less surface through which nourishment may be obtained. Thus growth may be retarded.

III. DISCUSSION OF RESULTS

The close bred forms on the basis of the characters studied in the given population have been found more variable as to both length and diameter, more highly correlated, and larger taking into consideration length and volume. The value of the conclusions in their application to the solution of problems of evolution is dependent on the logical application of cause and result as well as the methods of the investigation.

That the two groups of zygospores are comparatively close bred and cross bred will scarcely be denied, particularly when it is remembered that in lateral conjugation nearly all adjacent pairs of cells in a filament had united in the process, each pair producing a zygospore, all pairs having originated from the same cell. With the material taken from a part of a mass a few centimeters square, a sample of a whole population has been utilized, and from what is known of the reproduction of *Spirogyra*, it may be assumed with reasonable certainty that the entire mass had its origin from zygospores produced in a few filaments the preceding year. With practically all zygospores measured in each filament, the criticism that isolated zygospores of mixed descent were studied, and that greater variability would be expected in

those produced by lateral conjugation, loses its force. Furthermore it is believed that all investigations thus far made, upon analysis support the direct conclusions which follow.

It may be objected that cells of mature filaments originating from the zygospores should have been studied. While this would have been of interest, the zygospores themselves are individuals in the cycle of development, and the differences as represented in the groups chosen can not be said to have less value than data from another part of the life cycle.

The possibility of the results being affected by the swelling of zygospores due to the 2 per cent formalin used in preservation, became apparent when other duties prevented measurements within the anticipated time. The first series of 358 zygospores was measured between April 2 and May 16, while the remaining 42 were measured between August 17 and 21. The question seemed an important one, and in order to test the extent of such an error if present, the average diameter of the last lot was compared with that of the first lot, the values being 29.15 m. and 29.08 m., the difference of 0.07 m. being well within the limits of the probable error. The 42 zygospores measured August 17-21 happened to consist of an equal number of lateral and scalariform individuals, which would thus tend to eliminate an error should it have occurred. Consequently the use of the formalin does not appear to have affected the results.

Some evidence has been presented that new phylogenetic characters are more variable than older characters. Thus if lateral conjugation was a recent acquisition the greater variability might have been expected. Pearl and Clawson ('07) found a higher variation in the great chela of the crayfish, *Camburus propinquus* Girard, than in the protopodites of the 2 and 3 legs, nevertheless they preferred to attribute the result to ontogenetic rather than to phylogenetic factors. MacDougall, Vail and Shull ('07) stated that

the greater variability of phylogenetically new characters as compared with older ones . . . is confirmed . . . (p. 89).

The conclusion is open to objection inasmuch as they were comparing a hybrid with a single parental type and in general the greater variability would be expected. Consequently even admitting that lateral conjugation has been a more recent development than scalariform conjugation, it would not be demonstrated that an error had thus arisen.

1. *Comparative Variability*

Within the limits of the characters studied so far as the present material is concerned, it is evident that the zygospores produced by close breeding are more variable than those produced by cross breeding. While it is another proposition to extend the conclusion and insist that organisms produced asexually, by pure lines, or by close breeding, are more variable than those produced sexually or by cross breeding, it would seem that the facts strongly support such a conclusion and in connection with the evidence afforded by the investigations of Warren, Casteel and Phillips, Kellogg, and Wright, Lee and Pearson, it certainly may be denied that amphimixis or cross breeding as compared with other types actually produces variations, as has long been the prevalent belief.

The question here of particular interest, however, is that of the excess type of variability represented in *Spirogyra*. Inasmuch as the material was homogeneous in every way, it may be asserted that the greater variability exhibited by the close-bred forms is not fluctuability due to environment. It is also evident that, theoretically, cross breeding produces a greater number of combinations than inbreeding, nevertheless that the variability thus resulting is overwhelmed by that of another type in nature, is clear from the results noted in the preceding pages. An excellent demonstration of such condition is obtained by recalculating constants obtained by Hayes ('12) as shown in the accompanying table based on data obtained in connection with the breeding of *Nicotiana tabacum*.

Here the constants of No. 3 and No. 8 have been obtained by combining the two parental types (401 and 403)

both for the number of leaves and the height of the plant, and it may be noted that the coefficient of variation has dropped from 19.55 to 9.40 in the one case and from 17.35 to 13.60 in the other case. Thus variability as measured statistically has decreased. Those who have advocated an increased variability as the result of hybridization are correct when comparison is made of the F_2 generation with the F_1 generation or with a single parental generation. They are not correct, however, in making a general statement that cross breeding increases variability since the variability of the group composed of both parental types must be considered and upon so doing, it may normally be found that there has actually been a decrease in variability.

The possibility exists however that the variability will appear to have been increased when forms having the same phenotype but different genotypes are bred together. Such a condition may be illustrated by the two strains of white sweet peas crossed by Bateson which produced purple flowers in the first (F_1) generation, and purple, pink, mixed and white flowers in the second (F_2) generation. New combinations had arisen, but only as an expression of that which already existed in the phenotypes, for there is no evidence of an increase in unit characters nor was there an actual increase in variability.

There are only three papers of a statistical nature in which it has seriously been asserted that cross-bred forms or conjugating forms produced greater variability than resulted in close-bred forms or non-conjugating forms.

The first is that of Castle, Carpenter, Clark, Mast and Barrows ('06) based on a series of observations as to the effect of cross breeding and close breeding on the variability and fertility of the small fruit fly *Drosophila ampelophila* Loew. In conclusion it was stated that "inbreeding did not affect the variability in the number of teeth of the sex comb of the male, nor the variability in size," the first opinion resulting from the value of the coefficient of variation in the number of tibial spines, the second from the standard deviation in the length of the tibia. In the former case the data certainly do not

permit a clear conclusion one way or the other. In the second case, however, if the value of the coefficient of variation is computed for the length of the tibia—which, strange to say, was not done in the original investigation—and thus allowance made for the greater length of tibia in the cross-bred forms the average variability of the three inbred groups is 68 per cent greater than that of the cross-bred group. Consequently, the results decidedly support the facts in the present paper.

The remaining papers are those of Jennings ('11 and '13) in a study of *Paramecium*. In the first paper the breeding experiments are summarized as follows:

The progeny of conjugants are more variable, in size and in certain other respects, than the progeny of the equivalent non-conjugants. Thus conjugation increases variation.

It seems difficult to account for this conclusion if one subjects the data to a critical review. So far as a "pure race" is concerned the non-conjugants and their progeny were decidedly *more variable* than the conjugants and their progeny, although the small number utilized March 31 for the statistical work (42 and 34) is not sufficient to justify a conclusion in either direction. Even in a "wild culture" the evidence is too conflicting to justify a definite expression of opinion. Of the seven comparisons here made among the progeny, five showed an excess variability for the conjugants, but in only one case did the difference exceed three times the probable error, while two cases showed an excess variability for the non-conjugants, the difference in one case exceeding twice the probable error. Data from numbers so small (22-95) can scarcely be considered reliable. The comparison of the variability of "all pairs" and "all unpairs" on June 22 and June 23 denotes an excess variability for those completing conjugation at the beginning of the experiment.

In the second paper Jennings concluded (p. 363) that conjugation increased the variation in the rate of reproduction. The variation was increased, but the explanation of such increase seems comparatively simple when it is noted that among the conjugants there were many with a low rate of fission with death occurring. As com-

pared with the more normal rate of fission among non-conjugants, this could result in nothing but an increased variability, having, however, no bearing on the question at issue.

At the present time, therefore, it would seem that the preponderance of evidence demonstrates that variability is decreased in cross breeding.

2. Comparative Size

The zygospores produced by close breeding have a mean length of $62.38 \mu. \pm .18 \mu.$ with a mean diameter of $29.66\mu. \pm .10\mu.$ and those produced by cross breeding have a mean length of $60.44 \mu. \pm .13 \mu.$ with a mean diameter of $29.725 \mu. \pm .08 \mu.$ Thus so far as length is concerned the close bred zygospores are relatively 3.2 per cent larger and although slightly smaller in diameter, when volume is considered by utilizing the formula ($V = \frac{1}{6}\pi ld^2$) the close bred forms are also 2.8 per cent larger. Since these results are not in accord with the general belief that cross fertilization increases size and vigor, terms which have a diverse usage, however, it will be well to consider other evidence bearing on the problem with a view of attempting an explanation which may meet the conditions imposed.

Pearl ('07) in studying the conjugation of *Paramecium* with particular reference to assortative mating, notes that "the conjugant individuals when compared with the non-conjugant, are shorter and narrower" and stated in accordance with Calkins ('02) that the reduction in size was quite probably dependent on functional changes connected with reproduction. In *Spirogyra*, however, both the close-bred and the cross-bred zygospores go through similar reproductive processes in consequence of which one may question the theory that the method of conjugation is the decisive factor in bringing about the result even in *Paramecium*.

Jennings ('11) in comparing the size of conjugant and non-conjugant *Paramecium* stated that

The progeny of conjugants . . . were a little larger than the progeny of non-conjugants and the difference appears to be significant.

This conclusion was based on measurements of length and diameter, the volume not being computed. When this is done as shown in the accompanying table by utilizing the formula $V = \frac{1}{6}\pi ld^2$, thus allowing for slight decreases in diameters, the facts present a different interpretation.

Three (*a*, *b*, *c*) of the four experiments dealing with a "pure race" of *P. aurelia* indicate that the progeny of the non-conjugants become larger, even when as a group they are smaller (*a*, *b*?) at the beginning of the experiment. While the fourth (*d*) indicates a reverse condition so far as the measurement of October 30 are concerned, the measurements of the sixth and seventh generations immediately preceding, demonstrate that the non-conjugants were larger. The result on October 30, where the non-conjugants became smaller, may have depended on the elimination suggested by "all existing progeny." The extraordinary diminution in length (140 μ . to 123.71 μ .) suggests some disturbing factor of metabolism.

The results of the experiment with a "wild culture" where progeny of "unpaired" and "paired" forms of *P. caudatum* (?) were considered, again suggested to Jennings the greater size of the progeny of the paired individuals (conjugants), a condition which was particularly evident in the first generation. But it must be noted that the disturbance of the function of conjugation in "unpairing" may have produced the result. The progeny of the "unpairs" were relatively becoming larger from the first to the seventh generation. These facts taken together with the absence of measurements of mean diameters by which to calculate the mean volumes, suggest that such a conclusion based on that part of the work could not be accepted, and that the data strongly support the proposition directly contrary to Jennings that the progeny of conjugants tend to become smaller than the progeny of non-conjugants although the latter may be larger directly after conjugation as a result of slower fission. Thus the evidence from various sources, although incomplete, suggests that cross-bred unicellular organisms are smaller than close-bred forms.

Among multicellular organisms however it has long

been recognized that hybrids usually grew to a larger size than either parental form, as has been observed by Kohlreuter ('63), Knight ('99), Gärtner ('49), as well as Darwin, Mendel and others, although the cause of the increased growth has been purely conjectural. It is quite evident that the result is due to either the increased number of cells, a suggestion made by East, to the increased size of the cells, or to the combination of both conditions.

The question immediately arises as to the cause of the increased size and vigor among cross-bred multicellular organisms when the evidence indicates that cross-bred unicellular organisms are smaller instead of larger. Some investigations in progress¹ suggest an answer meeting the conditions, although more than a provisional opinion may as yet not be ventured. This is to the effect that the cells of cross-bred multicellular organisms are actually smaller than the cells of pure line or inbred organisms, and that the more rapid division is a function of the greater ratio surface has to volume in a small cell with the better opportunity this afforded for an increased metabolism.

The increase of size in plant and animal forms to the physiological limit has great importance for the future of agriculture and stock breeding, but many subsidiary problems must be solved before practical results are attained in this direction. The relative rate of growth, number and size of the constituent cells of pure line and of hybrid individuals is one of the problems.

3. *Comparative Correlation Resulting from Close Breeding and Cross Breeding*

The close-bred zygospores are more correlated as to length and diameter than the cross-bred zygospores, but since the difference only slightly exceeds twice the probable error, the value of the result here is questionable. Considering other investigations, it may be noted that the group containing close-bred, asexual or non-conjugating organisms, is more highly correlated in respect to characters than the group consisting of cross-bred, sexual,

¹Walton, ('14).

or conjugating organisms, although two exceptions, No. 12 and No. 14, are presented. An interesting fact, although possibly only a coincidence, is that cross bred zygospores of *Spirogyra* and of conjugating *Paramecium* have approximately only one half the correlation exhibited by close bred zygospores of *Spirogyra* and by non-conjugating *Paramecium*.

The explanation of the conclusion here reached, that the value of a character "x" in cross-bred forms does not have the same tendency to change that the value of a related character "y" has in close-bred forms, apparently rests on a Mendelian basis. Its importance in evolution, beyond the idea that more pronounced temporary combinations are thus allowed in the trial and error plan of nature, is conjectural.

4. *Amphimixis and Death*

With the assumption that the results obtained in the preceding investigation, together with the data presented by other writers, when correctly analyzed, strongly supports the view that asexually produced organisms tend to be more variable than those produced by the union of two gametes, there is furnished evidence for the interpretation of the origin of sex—amphimixis and also for the origin of death that would seem to rest upon a much more secure basis than the purely speculative theories of Weismann, Nägeli, Hatscheck, Metschnikoff, Minot, etc., which have previously been advanced.

The chief advantage gained in the reduction of variability, while somewhat conjectural, would appear to be that of holding organisms within limited bounds, or in other words, *asexually produced organisms in general tend by their variability to exceed the limits of their environment and thus perish, while organisms produced by the mingling of two diverse lines of germ plasm with their lessened variability meet the conditions of the comparatively slowly changing environment and their race persists.* This idea was proposed entirely upon speculative grounds by Hatscheck ('87) who suggested that

variation would run riot if not controlled by the union of germ cells, and it would now appear that the facts support such a proposition. While it has been suggested that the chief function of amphimixis was that of rejuvenation, a consideration of the discussion on "Comparative Size" as well as the recent experimental results obtained in the production of *Paramecium* do not support such an opinion to the exclusion of the hypothesis here put forward. East and Hayes ('12) have advanced the theory that recombinations in accordance with Mendelian principles were the chief purpose of amphimixis. While new combinations are thus brought about, apparently there exists a real difficulty in understanding how transitory heterozygotic forms could become of selective value in originating and maintaining such a process.

The acceptance of the conclusion that asexually produced organisms are more variable than those produced by amphimixis, and that thus some of the units are more readily subject to the eliminating influences of the environment, affords a comparatively simple explanation of the origin of death in multicellular forms which are built up of such units—the cell. Consequently the inference is that¹ *death occurs as the result of the continually forming body cells becoming so variable through the absence of control by amphimixis, that eventually some one group fails to meet the limits imposed by the environment, and these together with the remainder of the colony—the individual—perish.* The experiments of Woodruff ('11, etc.) who in extending the work of Maupas and of Calkins was able to rear several thousand generations of *Paramecium* without conjugation, as well as the investigations of Harrison subsequently elaborated by Carrel, where human and other animal tissues maintained cell division for a prolonged time in an artificial medium, are here of much interest. In each case the result is brought about by the favorable artificial environment, and it is made more clear that death itself is wholly or in part due to the unfavorable conditions surrounding an organism.

¹Walton, *Science*, p. 935, 1912.

IV. A WORKING HYPOTHESIS OF EVOLUTION

Investigations during the last fifteen years, instead of establishing evolution as the simple process of natural selection conjectured by Darwin and others, have made it evident that the results are due to many factors of much complexity. While the diversity of organisms depends on variation—their inheritance and non-inheritance—it is becoming more and more apparent that the term is too comprehensive and covers variations arising in organisms from causes quite different from one another.

The results reached in the preceding pages indicate the need of extending the older terminology as used by Plate, '13, and others where variations are separated into "somations" or fluctuations induced by the environment and not inherited, and "mutations" or blastovariations arising in the germ plasm and inherited, if a clearer understanding is to be obtained of evolution and its application. Therefore the following scheme is proposed.¹

VARIATIONS

- A¹. Apparently originating in accordance with definite laws A. NORMATIONS.
- B¹. Induced by general environmental stimuli, (food supply, use and disuse, etc.), but not inherited so far as evidence shows 1. *Fluctuations*.
- B². Not induced by environmental stimuli; inherited.
- C¹. Arising through the transference of factors by the combination of two ancestral lines in accordance with Mendelian principles, but exhibiting "per se" no definite progress 2. *Amphimutations* ("mutations" in part).
- C². Arising through causes at present unknown, but which, from the progressive results obtained, may be assumed to originate in accordance with definite laws 3. *Cumulations*.²

¹Several interesting groupings of variations have been suggested by Spillman, Baur and others, none of which, however, appear to meet present conditions.

²Cumulations—from cumulo, to increase—including the names of the following groups, with the exception of fractionations proposed by Bateson, are based on the apparent origin of the variations.

- A². Apparently not originating in accordance with definite lawsB. ABNORMALITIES.
- B¹. Induced during early developmental stages of the embryo from intracellular (?) stimuli, and inherited.
- C¹. Arising through the abnormal segregation of the hereditary material (chromosomes?).....4. *Malsegregations*
("mutations" in part).
- C². Arising by the loss of hereditary qualities.
- D¹. Resulting from the functional loss of a factor controlling a character5. *Defactorations*
("mutations" in part).
- D². Resulting from the partial functional loss of a factor controlling a character.....6. *Fractionations*
("mutations" in part).
- B². Induced during the early developmental stages of the embryo from extracellular (?) stimuli and not inherited7. *Malformations*.¹

While any scheme presented must change as new facts are obtained, a terminology is of value in proportion as it gives a basis for future progress. The objection that it is not possible to point out a specific cumulation by no means indicates the absence of such progressive variations taking long intervals of time, by the haphazard method of nature, in which to bring about a change evident to mankind. That the weight of evidence, so far as investigations have gone, is against evolution by means of the other variations noted, makes the explanation the more plausible. While it is true that Bateson ('14) has urged the consideration of the proposition that organic changes occur through the loss of inhibiting factors—defactorations—such a double negative theory assumes a decreasing complexity instead of an increasing complexity of protoplasm, as already pointed out by Castle, ('15) and seems impossible to maintain.

On the interpretation here presented, the diversity of organic forms is more complex than earlier imagined, and the problem of positive racial improvement is still far from solution. Loss as well as segregation factors

¹Many so-called malformations originate as defactorations, etc.

may add new forms which really contain nothing new. To build up and not to break down is the desideratum, and the data obtained would seem to suggest that pure line breeding with the employment of statistical methods to show any progress would be the path leading most directly to the goal.

V. CONCLUSIONS

1. *Direct Conclusions*

The following conclusions drawn from the investigation are primarily statements of fact.

1. Zygospores of *Spirogyra inflata* (Vauch.) produced by lateral conjugation or close breeding (quasi-parthenogenesis) are relatively 26 per cent more variable in length and 31 per cent more variable in diameter as measured by the coefficient of variation, than those produced by scalariform conjugation or cross breeding (sexual reproduction).

2. The size (volume) is greater in the average (mean) zygospore close bred by lateral conjugation, where the mean length is $62.38 \mu. \pm .178$, than in the average zygospore cross bred by scalariform conjugation, where the mean length is $60.44 \mu. \pm .135$. The diameter is approximately the same in both types.

3. In zygospores produced by lateral conjugation there exists a positive correlation between length and diameter of $.1894 = .0460$, while in scalariform conjugation the value is $.0934 = .0473$. This is in general agreement with results obtained by others although here the difference is not significant when the probable error is considered.

4. In the material studied approximately 45 per cent of the zygospores were formed by lateral conjugation, the remaining 55 per cent by scalariform conjugation.

5. The material studied was strictly homogeneous, and evidently arose from the same parental stock, both types of filaments being intermingled with no structural differences except those of conjugation. Consequently the differences in variability are not the result of fluctuability.

2. *Indirect Conclusions*

The conclusions here presented are generalizations based on the present investigation as well as the work of others, and represent propositions concerning which differences of opinion may exist.

1. Amphimixis, cross-breeding, etc., decreases and does not augment variability (cumulability) although amphimutability may temporarily be increased.

2. Close bred forms are more highly correlated in respect to related characters than cross-bred forms.

3. Variations, so far as their origin is concerned, may be separated into (A) Normations consisting of (1) fluctuations, (2) amphimutations, and (3) cumulations, and into (B) Abnormations consisting of (1) malsegregations, (2) defactorations, (3) fractionations, and (4) malformations.

4. Cumulations may best be investigated among organisms produced asexually, by pure lines, or by close breeding than by cross breeding, etc.

5. Sexual reproduction and cross fertilization have been advantageous in the evolution of organisms by limiting cumulability and thus confining the progress of the group to a path bounded by the more permanent environment.

6. Death occurs as a result of the continually forming body cells becoming so variable through the absence of control by amphimixis, that eventually some one group fails to meet the limits imposed by the environment, and these together with the remainder of the colony—the individual—perish.

3. *Hypotheses*

The following opinions in the nature of hypotheses based to a large extent on the preceding work may be confirmed or invalidated by future investigations.

1. Variability (cumulability) will be greater in a small and isolated population than in a large and less isolated population.

2. Progressive evolution has resulted from factors arising through cumulations without reference to amphimutations (Mendelian combinations).

3. Characters once established by cumulations produce by fluctuations, amphimutations, etc., the diversity of organic life. Such secondary variations are only indirectly the products of evolution.

VI.

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GAMETOGENESIS IN PLANTS*

The evolutionary origin of the reproductive cells furnishes one of the most fundamental problems connected with genetics, for upon a clear understanding of the subject depends the satisfactory solution of many subsidiary problems relating to animal and plant breeding. The value of hybridization and inbreeding; the meaning of the pure line hypothesis; the principle of cumulability, etc., may here be mentioned. Therefore, whether or not one agrees with the conclusions presented, studies from widely divergent standpoints which bear upon the question are to be welcomed. It is only through an analysis of the opinions thus advanced that there will develop a perspective which will eventually permit the solution of the problem.

It is in this connection that the conclusions of Professor Coulter as set forth in "The Evolution of Sex in Plants"¹ are of interest, representing as they do the views of one whose attainments in biology have by no means been confined to the field of plant morphology. Presented in a clear and interesting manner so far as the facts are concerned, the volume furnishes a valuable résumé of the subject from the botanical standpoint. It is evident, however, that a certain narrowness must exist in such a presentation, for a problem of this nature demands that plant biology and animal biology supplement one another from the experimental as well as from the morphological and cytological side. Gametogenesis had its beginning not, as Coulter suggests, among organisms far above the most primitive plants, but among unicellular flagellate forms whose representatives partake of the nature of both plants and animals and from which have arisen the various groups of plants in general. Sexuality, once hav-

¹By John Merle Coulter, head of the department of botany, Univ. of Chicago. Univ. of Chicago Press, December, 1914.

*Reprinted from *The American Naturalist*, vol. 50 (1916), pp. 498-501.

ing arisen, may have been partially or even wholly suppressed in various plant groups, but its subsequent reappearance by no means makes it necessary to affirm its polyphyletic origin. Our present knowledge of Mendelian behavior is of interest in connection with such a view.

It will be well to examine some of the more definite conclusions which Coulter has presented. Few of these are original, nevertheless they are of decided value since they are in most cases supported by unique observations bearing directly upon the point of view. It is merely unfortunate that the bibliographic references which would illustrate the development of the ideas are entirely absent, in consequence of which a false impression may be conveyed to many readers.

Early in the volume it is stated that sex in the higher animals has become the only method of reproduction. Logically this view is not to be maintained, as has already been pointed out by LeDantec ('03) as well as by Chamberlain ('05) evidently in ignorance of the conclusions reached by the previous writer. More recently Janet ('12) has considered the subject. If the criterion by which the sporophyte is to be distinguished from the gametophyte rests upon the $2x$ as compared with the x condition of the chromosomes, we find that among animal organisms the asexual phase has actually become the dominant method of reproduction and the sexual phase is represented only by the parasitic cells arising through the reduction division. In accordance with this view one is prepared to accept the spore mother cells of plants as homologues of the cells preceding the reduction division in animals. In a subsequent discussion Coulter states in accordance with the view first advocated that the animal body produces gametes and not spores. When reduction occurs at the time of the first maturation division in animal organisms it is quite clear that the cells thus produced may correspond to spores which in the next division give rise to gametes. It may even be asserted that they are megaspores or microspores dependent on the sex represented. When chromosome reduction is moved forward to the second maturation division, however, it is possible to agree with Coulter,

but seemingly more logical to admit that the change is a secondary one and that the first maturation cells may still represent the spore cells.

In accordance with the proposition that spores unite as gametes to form a single cell, evidence should either be presented to show that an identical chromosome composition exists between the actual spores and the so-called spores functioning as gametes or consideration should be given to subsequent reduction division. Otherwise the conclusion scarcely merits the value of an opinion. Furthermore, the argument that the fusion of a sperm and cell among the angiosperms to form a nutritive endosperm justifies the conclusion that pairing and fusing do not represent the essential features of sexuality, can not be considered. This is only one of numerous examples where changes in form or function of parts occur without having any bearing on the actual origin of the part. Even in this case a fusion is represented and may have a value similar to that among gametes.

It is in connection with "A Theory of Sex" that it seems necessary to decidedly differ from Professor Coulter. Here the two main theses are that sexuality has arisen (1) to carry an organism through an unfavorable environment, and (2) to make evolution more rapid by presenting a greater diversity of forms.

The first deduction is based on the proposition that gametes in many plants are produced at the close of the vegetative period. Such a conclusion — *post hoc ergo propter hoc*—does not rest upon a sound basis. With the fulfillment of a function having the importance of a gamete production, it is quite logical that the cycle of development should close, but to state that the closing of the cycle has brought about the production of the gametes, is quite another thing. The acceptance of this would lead to the inference that gametes arose in fresh or brackish water forms where pronounced seasonal changes took place and not in larger bodies of water like the ocean, the most probable place.

The second deduction is a restatement of a conclusion reached by Weismann ('76) to the effect that amphimixis

increases variability with the assumption that variations thus assumed to be produced are inherited in a cumulative manner. The evidence, however, available at present, supports a view directly contrary to this, namely that the gametic condition makes evolution slower by decreasing the diversity of available forms. Mendelian combinations—amphimutations—may occur but the result is a decrease in variability when the parental populations are compared with the F_2 or with a succeeding generation. The amphimutations are transitory and there is no evidence that they present anything actually new in themselves.

Regardless of the opinions here at variance some of which can only be established as sound generalizations through long experimental investigation, the summary of gametogenesis by Professor Coulter will be read with profit and pleasure by those interested in problems of evolution as well as by those particularly concerned with plant morphology and development.

THE AXIAL ROTATION OF AQUATIC MICRO-ORGANISMS AND ITS SIGNIFICANCE*

Some studies concerning the axial rotation of aquatic microorganisms occupying my attention during the last two years, have yielded results which it is believed are of decided importance in connection with the principles underlying evolution.

In general it may be stated that the positively phototactic free swimming forms of the northern hemisphere rotate clockwise, assuming the observer in front of the advancing organism, and the negatively phototactic forms counter-clockwise, while in the southern hemisphere there are reverse conditions. The apparent exceptions thus far noted have been found closely allied to northern forms and may have been introduced subsequent to the origin of the southern forms.

The evidence although far from complete is gradually accumulating that the characteristic is one which has been gradually impressed upon the organisms through the rotation of the earth and the apparent path of the sun from east to west. Any attempt to account for it on the basis of natural selection can scarcely gain credence. While the possible effects of the angular velocity of the earth or of certain electrical conditions may be considered, it does not seem that the result could in this way be explained. Experimental attempts to reverse or to diminish the rapidity of the rotation of the organisms have thus far failed.

The problem is an interesting one from the geophysical as well as the biological point of view, and many interesting principles come under consideration. Among these may be mentioned the Pendulation Theory, Bipolar Distribution, The Twining of Plants, The Tropism Theory, etc. Similarly the direction of the spirals in *Spirochaeta*, *Spirulina*, *Arthrospira*, *Spirogyra*, etc., are of interest.

*Reprinted from *The Ohio Journal of Science*, vol. 18 (1917), pp. 6-7.

Modern genetics throws light on the distribution but not on the origin of the character producing genes or factors. These units have in general long been in existence. It is to some such principle as the one suggested that we must look for evidence sufficiently definite to overcome the prejudice which has arisen against the old acquired character ideas as to the fundamental origin of characters.

There is need of studying, in this connection, the behavior of microorganisms near the equator as well as in the southern hemisphere, particularly in an experimental way, before definite conclusions may be drawn.

EUTETRAMORUS GLOBOSUS, A NEW GENUS
AND SPECIES OF ALGÆ BELONGING TO
THE *PROTOCOCCOIDEA* (FAMILY
CÆLASTRIDÆ)*

While studying the plankton from "Mirror Lake," a small pond on the campus of the State University at Columbus, Ohio, exceedingly rich in phytoplankton at certain times of the year, a form quite unique in structure was noted with much interest. It consisted of 16 cells, each containing a chloroplast, the cells being arranged in groups of fours and imbedded in an almost invisible gelatinous matrix. The organism was non-motile with no trace of flagella. The preparation was one taken from a sterilized specimen bottle filled with water and floating algæ—mostly *Cladophora*—at the margin of the lake, Oct. 9, 1915, the observation being recorded a few days later. An interval of over two years has elapsed during which period various samples of water from the lake have been studied without again noting the species, however.

The organism is referable to the Family *Cælastridæ* (*Cælastraceæ*) of the *Protococcoidea*¹ and constitutes a new genus quite different from forms thus far known. The drawing is taken from a camera lucida sketch made at the time with a Leitz Binocular, 2 mm. apochromatic objective.

Eutetramorus n. g.

Cells non-motile, light chlorophyl green; united into a colony of 16 cells arranged in groups of 4's within a gela-

¹The endings of the Class and Family names are identical with those utilized in a systematic review of the typically unicellular forms which will be published shortly. They are an extension of those proposed by Poche (1911). Nomenclatural methodology, particularly among the primitive plant-animal organisms is in a somewhat chaotic condition.

*Reprinted from *The Ohio Journal of Science*, vol. 18 (1918), pp. 125-127.

tinous like mucous covering; plane of each series of 4 cells perpendicular to the square included by the groups.

Represented by a single species.

E. globosus n. sp.

Cells spherical, containing a chloroplast with central pyrenoid, the 16 cells united in groups of 4's, the distance between each group and the adjacent lateral group being approximately one and one-half times the diameter of the individual cell; reproduction unknown.

Diam. (single cell) 5μ . (colony) 30μ .

Distribution, Mirror Lake, Columbus, Ohio (U.S.A.).

Habitat, surface water at margin of lake.

The relationship of the form to *Cœlastrum* and the other allied genera of the family seems clear, although the systematic position must be a provisional one until the method of reproduction is known. In its organization it represents the lowest form of the family where a definite colonial organization is attained.

Kofoid (1914) has recently described a new genus and species, *Phytomorula regularis*, from a reservoir at Berkeley, California, which is allied to *Cœlastrum* and is of unusual interest in that it represents a 16 celled colonial form extremely flattened, the cells being contiguous although not arranged in the same plane. The species was extremely rare and he had been unable, at the time of the presentation of the paper, to obtain information as to its method of reproduction.

The family *Cœlastridæ* now consists of five genera which may be separated in accordance with the table given below. Three of the genera have an extremely restricted distribution which, however, may be the result of their comparatively rare occurrence. *Eutetramorus* is based on a single specimen obtained at Columbus, Ohio. *Phytomorula* is described from a very few specimens obtained in a reservoir at Berkeley, California. *Burkillia* is known only from Burma. The remaining two genera, *Cœlastrum* and *Sorastrum* are abundant and have a wide distribution. The genus *Hariotina* based by Dangeard (1889) on *H. reticulatum* is now included with *Cœlastrum* while *Selenosphaerium* of Cohn (1879) is placed with *Sorastrum*.

TABLE OF GENERA.

- A¹ Cells comparatively smooth or at least not developing acute processes or spike-like appendages; colonies with cells regularly arranged, usually approximating the form of a sphere, which may be extremely flattened.
- B¹ Colonies formed of 16 cells; form not that of a true sphere.
- C¹ Cells arranged in groups of fours, the groups not contiguous; colony not flattened.
1. Gen. *Eutetramorus*
- C² Cells not arranged in groups of fours; contiguous; colony flattened 2. Gen. *Phytomorula*
- B² Colonies formed of 2-32 cells; form approximately spherical 3. Gen. *Cœlastrum*
- A² Cells developing acute processes or provided with acute or spike-like appendage processes; colonies with cells not regularly arranged, not approximating the form of a sphere.
- B¹ Cell walls gradually narrowed into an acute process.
4. Gen. *Burkillia*
- B² Cells provided with spike-like appendages or elongate processes. 5. Gen. *Sorastrum*

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ORGANIC EVOLUTION AND THE SIGNIFICANCE OF SOME NEW EVIDENCE BEARING ON THE PROBLEM*

I.

The biological problem recognized as having the greatest fundamental importance at the present period is that problem of evolution relating to the means by which the heritable characters differentiating various organisms from one another were first called into existence, or granting the validity of the gene hypothesis and speaking more concisely, how hereditary character-forming genes have originated in the process of evolution. That the diverse forms of life found upon the earth are only to be explained as the result of organic evolution, is a proposition which scarcely needs be mentioned at the present period in the history of science, at least so far as individuals endowed with minds reasonably logical in evaluating evidence are concerned. It is not evolution as a process going on in the world which is being particularly questioned nor the general method by which characters once having originated are inherited, but the particular method by which heritable characters first arose.

The purpose of the essay here presented is threefold. *First*, that of pointing out the unsatisfactory nature of much of the earlier evidence as a basis for sound generalizations in connection with a clear understanding of evolution. *Second*, that of calling attention to the serious shortcomings of modern methodology in throwing light on the causative factors of evolution. *Third*, that of presenting some new evidence somewhat unique in its nature, based in part on preliminary experimental work, to the effect that the environment acting through long intervals of time may impress characters upon an organism which become unalterable by reversal processes.

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To these propositions may be added the suggestion of the fundamental importance which physico-chemical methods must play during the future in solving the problems of evolution.

II.

The controversies relating to evolution have been many. When, however, one considers the interest attached to the subject, its broad bearing on various phases of human welfare—sociology and economics in general, animal and plant breeding in particular—together with the difficulties of interpretation which apparently have increased rather than diminished during the sixty or more years seriously devoted to its elucidation, it is not at all surprising that many different conclusions have been reached, many dogmatic statements presented, and many acrimonious discussions engendered.

In connection with a clearer understanding of the points at issue, it will be well to pass certain historical details relating to the development of the different theories somewhat critically in review. This is done even at the risk of a repetition of facts quite familiar to those who have taken more than a passing interest in the subject.

For long the theory of natural selection dependent on the inheritance of small chance variations received general acceptance. Championed by Weismann in his notable controversy with Spencer to the exclusion of the Lamarckian idea that characters acquired through environmental stimuli were heritable, it seemed at the time entirely plausible as an explanation meeting the conditions.

With the greater attention given to experimental methods, however, doubt arose concerning the fundamental value of selection and resulted in the presentation of the mutation theory by DeVries. Here evolution was interpreted as arising from sudden and comparatively extreme variations passed on by inheritance in nearly an unchanged condition. Once more the results of experimental work along the lines of the rediscovered principle of Mendelian segregation indicated to a large number of students of evolution that the facts set forth by DeVries were subject to quite another explanation, in itself having no bearing

on the origin, but merely on the redistribution of the character-forming units already present in the stock utilized. Another explanation not taking into account the purity or impurity of the parental stock, accounted for "mutations" through the sudden ineffectiveness or loss of a gene.

The dissatisfaction thus arising resulted in the return of many to the fold of "acquired characters." Semon (1912) reviving the "mneme" principle received the support of Wettstein, Przibram, and others. A disinclination existed, however, among most naturalists to accept the evidence presented as seriously upholding the inheritance of new characters produced by environmental stimuli. Explanations of the results on quite other grounds seemed more plausible. For example, the work of Tower (1906), (1910), etc., in attempting to control the color pattern of the potato beetle by changes in temperature and humidity, encountered the impurity of the germplasm objection as well as the gene loss objection, either one of which would be fatal to the validity of the conclusions, if sustained. Commenced at a period in 1895, prior to the rediscovery of the principles dealing with alternative inheritance, and finished in 1904 before the facts were duly appreciated, it is not at all improbable that genetic complications in the way of recessives, modifiers, losses, lethals, etc., were involved. The destructive criticism presented by Cockerell, Gortner, Bateson, Castle, and others, particularly in reference to the later studies of Tower (1910), makes it evident that the results must be confirmed from independent sources with more consideration to the possible errors mentioned before the conclusions are to be accepted.

Similarly, the work of MacDougal (1907), in connection with the modification of *Raimannia odorata*, one of the Patagonian primroses, may be explained. Compton, as noted by Bateson (1912), using the same species, was unable to obtain like results, while Humbert (1911) utilizing 7,500 pure line plants of *Silene noctiflora*, one of the "pinks" also failed to obtain so-called "mutants" similar to those found by MacDougal.

The investigations of Kammerer, Woltereck, Ferri-niere, etc., are of decided interest, but to those critically inclined they offer no evidence giving pronounced support to the proposition that environmental stimuli form new genetic factors.

Thus, in turn, have the theories as to the method by which evolutionary progress occurs been undermined by doubt. Feeling the insufficiency of small chance variations, of environmental variations, and of larger germinal variations, as a summation process, it is not to be wondered that the truth-seeking pilgrim has become wearied in his journey and longs for a more secure resting place.

III.

Let us return to the problem as suggested in the opening paragraph, namely the actual origin of heritable characters, and consider somewhat more carefully as to whether theories exist justified by facts, which will furnish acceptable evidence. There are two well-developed hypotheses, the general one of DeVries and the more specific one of Morgan and his associates, founded on discontinuous variations, and that of Castle based on continuous variations.

Considering the views of DeVries and his followers in the light of experimental investigations made during the last ten years, it has become more and more evident that by far the greater number, if not all, of the so-called mutations thus obtained, were explainable on the basis of the combinations of preexisting units of the germ cells. This rests upon the proposition that there are present in the gametes certain hypothetical entities to which the name gene or factor has been applied and which give rise to the heritable characters of an organism. Thus it is at once recognized that the problem relates to the origin of the gene, rather than to the origin of the apparent characters with which it is correlated, and that by far the greater number of so-called new characters are not new, but were performed at remote periods of time. So far as the present arguments are concerned, it matters not whether the results are assumed to be brought about by

material units or enzyme reactions. The prepared potentialities exist in either case.

As examples of extreme types of characters which may arise from the combinations of existing genes and which might have been considered "mutations" at an earlier period when the facts as to their origin were not fully known, one need only mention the "blue" of the Andalusian Fowl exhibited by the hybrid between the black and white parental stock, or the "pink" presented by the cross between the red and white "four-o'clocks" of *Correns*. A type of characters more in line with mutations which have been described and to which there is every reason for believing that many of them may be referred, rests upon multiple gene effects combined with sterility, in accordance with evidence presented by Davis, and others. Of decided interest in this connection is a recent paper by Muller (1917) calling attention to "An *Oenothera*-like case in *Drosophila*" where a result quite comparable to certain mutations of *Oenothera* is explained through the action of balanced lethal genes. There are other varying degrees of combinations from which "mutant" characters may arise and which depend on the behavior of the genetic material in connection with recessives, modifiers, lethals, crossovers, non-disjunction, etc.

There is really nothing extraordinary in the appearance and disappearance of the characters thus formed, beyond their interpretation, and this has furnished false premises for many erroneous conclusions, chief of which, in the opinion of the writer, is the mutation theory as outlined by DeVries in so far as it may account for progressive evolution.

Inasmuch as it seems probable that the results obtained by Castle are to be explained upon the same basis as those of DeVries, it will be well to consider them in this connection. Here it is assumed that a continuously variable heritable gene is involved, and that progressive results are obtained through the selection of the "unit characters" produced by such a gene. Castle, however, stands almost alone in vigorous support of such a variation, while opposed to him are the Hagedoorns, Morgan, Pearl, Punnett,

McDowell, Muller and others equally insistent that genes once having originated pass on from one generation to another unchanged except in comparatively rare instances where so-called "mutations" occur.¹ It is maintained by those advocating this view that the results in connection with hooded rats on which Castle bases his contentions, are due to an uncertain number of modifying genes not in themselves variable, and that the existence of such genes has been demonstrated in other organisms presenting results similar to those obtained in rats. The work of Little (1917) with mice where three segregating types of spotting were found to produce varying degrees of color pattern, indicates that multiple genes are involved. Furthermore, the analysis by Little of the data obtained by Castle, Phillips and Wright, points decidedly to the interpretation of their results on the basis of multiple genes instead of a continually varying gene.

It would thus appear evident that the theory outlined by Castle is open to quite the same objections that occur in connection with the mutation theory of DeVries, and that there is little evidence for believing that it has any fundamental value in explaining evolution.

The mutation theory of Morgan and his associates, based primarily on results obtained in studies of the small "fruit-fly" *Drosophila*, apparently presents quite another view of the subject. Here it is clearly indicated that evolution has taken place through the incorporation of mutant changes, and that these changes are due to discontinuous "mutations" of genes as exemplified in multiple allelomorphs.

Assuming the validity of the arguments based on linkage relations in respect to the localization of the genes,

¹Jennings (1917) has recently endeavored to show that the views of Castle and his opponents are identical. This, however, is by no means the case. On the one hand there is the idea of a continually variable gene (coat-color-producing gene in rats) moved gradually along a given scale by selection. On the other hand there is the idea of a rarely mutating gene (*e. g.*, sex-limited eye color producing gene in *Drosophila*) moving abruptly from one part to another of the scale. Its position once obtained remains for a long time constant. These differences of interpretation are at present irreconcilable.

Since this note was written, Morgan (1917) has discussed the matter in detail, presenting arguments quite similar to those mentioned above, and arriving at a similar conclusion.

the conclusion follows that the "mutation" results either (1) from a change in a specific gene or (2) from the complete linkage of a series of genes. If the latter proposition should be the correct interpretation, and it is by no means clear that it is not, the objections urged against the theories of DeVries and of Castle hold equally here.

Morgan and several others have presented evidence for believing in the specific change of a gene. Granting that this is the actual explanation of the facts presented in connection with multiple allelomorphs, etc., there are two lines of argument leading to the conclusion that these changes are results of combinational sub-units or sub-genes existing in the species, and that progressive evolutionary changes are no more represented here than in the previous theories of DeVries and of Castle.

The first argument (*a*) rests upon the recurrent "mutations" which have been noted in a considerable number of cases. Thus the sex-linked eye colors of *Drosophila* forming the multiple allelomorph system consisting of white, eosin, cherry, blood, tinged, and buff, and their dominant allelomorph, red, of the wild fly, have their origin from a single definite area or locus in the "X" chromosome, accepting linkage as a criterion. They have not arisen in a continuous series but as sudden changes from one extreme to another at comparatively long intervals. The character may remain modified in one direction and then suddenly revert to an original condition. Thus white changed to eosin and later back to white as noted by Morgan (1916). Furthermore, the changes are not extremely infrequent. A similar transformation has been noted by Emerson (1917) in maize where self color apparently changed to variegation and later back to self color. A variation which may be of the same type has been described by Shull (1911) for *Lychnis*. Quite recently Zeleny (1917) in studies on *Drosophila melanogaster* Meig. (= *ampelophila* Löw)¹ has noted a reversed mutation where full-eyed flies result from the return of the bar gene to the original full-eyed condition. In each

¹Sturtevant, mss.

of the cases mentioned the germinal purity of the stock was believed to be without question.

Such results are not to be attributed to a continuous series of mutations, to progressive changes, or to genetic losses. They clearly suggest that the gene, if it is the individual gene which is involved, is made up of smaller combinational units which through their permutations give rise to the characters in question. Presumptive evidence is certainly furnished against the idea that anything new has developed in the organism to form the particular characters. Furthermore, one may well believe that any particular mutation under observation sufficiently long, will exhibit recurrent changes.

The second argument (*b*), to the effect that the gene is comparatively stable and that "mutations" are only transitory combinational changes, is based on the maintenance of apparently identical genes through long periods of time. Thus Metz (1917) found that the three mutations which had, up to that time, occurred in *Drosophila virilis* Sturt. appeared exact duplications of the mutations in *Drosophila melanogaster* Meig.¹ In both species "confluent," a modification of the wing venation, is similar in form, dominant over "normal" and "lethal," when the fly is homozygous for the character. The characters "yellow" and "forked" are sex linked in both species and otherwise alike so far as the evidence exists. Inasmuch as the earliest representative of *Drosophila* thus far known is a species not decidedly different from those now existing as noted by Löw (1850), who described it from the amber of the Baltic Sea, and belongs to the Lower Oligocene of the Tertiary Period, with an age of from two millions to three millions of years, one must infer that the genes common to the two species mentioned have been preformed for a long period of time, and that nature has paid little attention to such mutational changes as occur in connection with multiple allelomorphs.

There are certain investigations widely separated as to their content, but apparently closely correlated as to the

¹The species are distinctly separated not only in external appearance but also by their chromosome number. *D. melanogaster* has four pairs, while *D. virilis* has five pairs of chromosomes.

underlying explanatory principles involved, which must not be overlooked in a consideration of the changes which may take place in hereditary units. These are concerned with the differences involved in metabolism.¹

On the one hand there are studies dealing with the direct effects of a changed metabolism on the developing individual. Here may be mentioned the work of Lillie in connection with the "free-martin" of cattle; Steinach on the transplantation of the gonads in rats and guinea-pigs; Goodale on the grafting of ovaries in male fowls; Pearl and Surface on the degeneration of the ovary in cattle; Riddle with pigeons, etc. On the other hand, there are studies dealing with the indirect effects on inheritance. Among these may be mentioned that of Goldschmidt with moths; Woltereck with daphnids; Plough with temperature effects on *Drosophila*; Hoge with the effects of cold on *Drosophila*; Morgan with the effects of moist food supply on *Drosophila*, etc.

As an example of the development group, the investigation of Lillie may be noted. The evidence obtained showed that the "free-martin" or sterile female usually developing where the twins are of separate sexes in cattle, etc., resulted from the modifying influences of the sex hormones in the male where the two chorions had anastomosed.

As an example of the inheritance group, Morgan has found that the "mutant" "abnormal abdomen" in *Drosophila* occurs in connection with a moist food supply. The character is a sex-linked dominant. If an abnormal male is bred to a normal female and the food is kept moist, the sons are normal and the daughters abnormal. If the food is dry both sons and daughters are normal. The reciprocal cross gives sons and daughters both abnormal with moist food but normal with dry food.

It follows then that in *Drosophila* the gene for the abnormality—or the chemical preparedness for the inhibition of normality, if one so wishes to term it—is per-

¹The theory has had a long historical development. Treat (1873) published a paper on controlling sex in butterflies as a result of food supply. Yung (1881) worked with tadpoles. Nussbaum (1897) with rotifers. Recent evidence of an elaborate nature has been presented by Goldschmidt, Woltereck, Whitney, Banta, Shull and others.

formed in the "X" chromosome and merely awaits a suitable environment before presenting itself as a character. Similarly, in connection with the changes occurring in the development of the "free-martin" of cattle, it seems necessary to admit that there are genes present in the sex chromosome concerned with the development of sexual characters which, however, are in a state of equilibrium, and that the inhibition or the excitation¹ of one or the other genes or groups of genes will result in the development of the corresponding individual.

From the facts presented, one seems justified in making the deduction that heredity hands down a framework which within certain limits allows a plasticity in the development, and that the direction of development is determined by physio-chemical influences through the suppression of potential units.

Thus the conclusion seems almost unavoidable that by far the larger number, if not all, of the heritable characters making up an organism, result from combinational units which have long been predetermined, and that the breeder, whether the semi-scientific agriculturist or the ultra-scientific drosophilist, is largely, if not entirely, engaged in presenting new combinations of existing units. If this be true, modern genetics has left the actual problem of evolution far to one side and deals only with results of a secondary, although none the less interesting, nature.

One is, therefore, led to inquire as to whether there may be available evidence which will permit a new insight into conditions governing the formation of characters, even though the evidence from its nature must be largely circumstantial.

IV.

Accompanying the progressive swimming movement of most aquatic microorganisms there is a characteristic axial rotation. This has been noted by Nägeli, Engelmann, Strassburger, Mast and more in detail by Jennings (1901) who has called attention to the value which such

¹It has been shown by Chapin (1917) that the gonads of the free-martin originally destined to be a female, attain a male condition.

a compensatory motion may have for the organism in which it exists. No explanation has been suggested other than this as to the origin of the rotation, and without further thought it is evident that one would be inclined to attribute it to natural selection, assuming that those individuals in which it did not occur were at a disadvantage in the struggle for existence by reason of their more confined movement.

It is the phase of the question dealing with the particular causes bringing about the rotation that appears to be of extreme significance when considered in connection with the principles underlying evolution and to be susceptible to quite another explanation than the natural selection implied by the term "adaptiveness" which, in accordance with Jennings (1906), is based on the idea that "it tends to preserve the life of the animal." Furthermore, when the groups of facts associated with the characteristic rotation are brought in review, it would seem that the explanation suggested may go far toward interpreting the origin of the fundamental activities as well as the origin of the characters in general of organisms.

In connection with the preparation of a systematic review of the order Euglenoidina belonging to the class Flagellata of the Protozoa (1915), it was noted with decided interest that a large number of the forms possessed an oblique striation ranging from almost indiscernible markings to characters of great complexity impressed upon a cellulose-like envelope (*e. g.*, *Euglena spirogyra* Ehrenb., *Phacus pyrum* (Ehrenb.), *Heteronema spirale* Klebs, etc.), the striæ extending forward and to the left. The character also appeared to be invariably correlated with an axial rotation of the organism from right over to left. Such a movement is to be described in physical terms as "clockwise," the position of the observer being in front of the advancing organism.

The facts took on additional interest when it was noted that forms with a reverse striation seemed entirely absent from the northern hemisphere, although such forms existed in the southern hemisphere.

Inasmuch as the euglenoids are in general positively

phototactic under normal conditions, it would immediately occur to one seriously considering the question, that the underlying principle producing the rotation was the turning of the earth on its axis, with the resultant apparent motion of the sun from east to west. Such a hypothesis would become the more tenable when it was found that negatively phototactic microorganisms of the northern hemisphere rotated as a rule in a reverse or counter-clockwise direction.

Some of the evidence thus far obtained may be presented more clearly in tabular form¹ (Table I). Thus

TABLE I

A series of aquatic microorganisms showing in general the clockwise rotation of positively phototactic forms and the counter-clockwise rotation of negatively phototactic forms in the northern hemisphere, with evidence for the tendency to reverse condition in the southern hemisphere.

Northern Hemisphere		
<i>Euglena viridis</i> Ehr.	Positive.	Clockwise.
<i>Euglena hæmogrammata</i> Walt.	Positive.	Clockwise.
<i>Euglena tripteris</i> Duj.	Positive.	Clockwise.
<i>Euglena spirogyra</i> Ehr.	Positive.	Clockwise.
<i>Leptocinlis ovum</i> (Ehr.)	Positive.	Clockwise.
<i>Phacus pyrum</i> (Ehr.)	Positive.	Clockwise.
<i>Cryptomonas ovata</i> Ehr.	Positive.	Clockwise.
<i>Pandorina morum</i> (Müll.)	Positive.	Clockwise.
<i>Eudorina elegans</i> (Ehr.)	Positive.	Clockwise.
<i>Volvox globator</i> (Linn.)	Positive.	Clockwise.
<i>Stentor polymorphus</i> Ehr. (=viridis) ..	Positive.	Counterclockwise.
<i>Phacus longicauda</i> Ehr.	Positive.	Counterclockwise.
<i>Stentor cæruleus</i> Ehr.	Negative.	Counterclockwise.
<i>Anurea cochlearis</i> Gosse	Negative.	Counterclockwise.
<i>Arenicola cristata</i> (larva)	Negative.	Counterclockwise.
<i>Chilomonas paramœcium</i> Ehr. ¹	Negative.	Counterclockwise.
Southern Hemisphere		
<i>Leptocinlis piriformis</i> Cun.	Positive?	Counterclockwise.
<i>Phacus bacillifer</i> Cun.	Positive?	Counterclockwise.
<i>Leptocinlis mammilata</i> Cun.	Positive?	Clockwise.

it may be stated that so far as the facts are available, positively phototactic forms with the exception of

¹The rotation direction and light responses noted are those taking place under normal conditions. The conclusions presented are not altered by the fact that as a result of stimuli under conditions imperfectly known, reverse movements may occur, e. g., the negative response of Euglenoids to intense light.

Stentor polymorphus Ehrenb. (= *S. viridis* aut.) and *Phacus longicauda* Ehrenb. rotate clockwise in the northern hemisphere. Inasmuch as the photactic relation of the ciliates in general is negative, where a reaction exists, it seems probable that the inclusion of the minute symbiotic forms of algæ, *Chlorella vulgaris* Beyer, which gives the species its characteristic green appearance, has induced a change from a negatively phototactic to a positively phototactic condition, while the organism retained its original counterclockwise rotation. Small forms like *Chlorella* which contain chloroplasts, are generally positively phototactic so far as their responses to normal conditions are known.

Phacus longicauda (Ehrenb.) is an euglenoid about 100μ in length, with comparatively flat wing-like expansions. The striæ covering the body are longitudinal. In swimming, however, many of the forms have the anterior part of the right expansion turned slightly down, while the left expansion is turned up in a similar manner. This gives their progressive movement a counterclockwise rotation.

In the southern hemisphere direct observation of the characteristic rotation has not been made, but inasmuch as the direction of the striæ indicates the direction of the rotation, certain evidence is available. Cunha (1913) in his studies of Protozoa from Brazil has figured several forms showing distinctly the arrangement of the striæ in the excellent plates drawn by himself. While it is not impossible that a careless investigator might focus on the lower part of the specimen, thus showing the reverse position of the striæ, the careful work of Cunha scarcely permits one to suggest such a criticism. It may furthermore be noted that the apparently counterclockwise rotating forms described by him are species quite different from the typical northern forms, while the forms which evidently rotate clockwise are closely allied to species from the northern hemisphere, and may have been introduced comparatively recently so far as evolutionary time is concerned.

The original development of the unicellular forms in the northern hemisphere with their subsequent introduction to the southern hemisphere by aquatic birds, etc., is well within the range of possibility and suggests that even should forms with reverse rotations be entirely absent from south of the equator, the hypothesis which has been proposed would by no means be invalidated.

Having presented the general facts as to the behavior of free-swimming microorganisms, it becomes advisable to consider the explanations which may exist as to the origin of the characteristic rotation. It seems impossible to attempt to account for such a character on the ground of "natural selection." One would be compelled to believe that the reverse rotation — the counterclockwise rotation of positive northern forms—possessed an elimination value, an almost indefensible proposition, particularly when forms like *Stentor polymorphus* and *Phacus longicauda* are considered as well as forms in the southern hemisphere which do not rotate in agreement with theory.

The most obvious explanation to be considered is that based on the influence which the sun in its apparent daily movement from east to west in the equatorial region may be supposed to have exerted on the flagellum. This assumes that the flagellum is the orienting factor and that the sun has induced in it an east-west rotary-like or whip-like propelling movement. The consequent mechanical effect would be that in the northern hemisphere forms with a positive light reaction would rotate clockwise and those with a negative light reaction would rotate counterclockwise. Conditions would be reversed for those which might be present in the southern hemisphere during the evolutionary stage.

Conversely, negatively phototactic forms would develop a reversed or counterclockwise rotation by means of the influence of the light rays on the stroke of the light-avoiding flagellum and their modified organs, the cilia. It is by no means necessary to believe that the stroke of the flagellum should be one of rotation, although theory would imply a partial rotation in the primitive flagellate

forms. The method of movement by means of the flagellum furnishes a problem of considerable difficulty which has received attention from several investigators, notably Delage and Herouard (1896), Goodspeed and Moore (1911), Bütschli and others.

There are several inferences of an axiomatic nature that follow from such an hypothesis. Forms near the neutral equatorial region may be assumed to possess a slower rotation than forms near the poles and at the same time there may be expected to occur a change in the relative angle which the striæ make with the longitudinal axis of the body, their direction becoming approximately parallel with that axis. The cosmopolitan distribution of unicellular organisms with the evident non-selective value of the character makes such a hypothesis difficult of demonstration. The application of statistical methods would be of interest, however.

A second explanation of the rotation direction, apparently, however, a negligible one, is on the basis of the angular velocity of the earth so far as it may have an influence on small bodies at its surface. With free-swimming microorganisms oriented in accordance with the axis of the earth during definite intervals and rotating in the same direction that the earth rotates, conditions are fulfilled for such a mechanical explanation. When, however, the relative dimensions of the earth and the organisms as well as the relative density of the earth, the water and the organism, are considered, it is difficult to believe that the explanation lies in this direction. While many of the forms are attached to some definite surface in the water during certain periods of their development, there are others which reproduce directly in the water and should this have been the primitive condition of development, the rotation of the earth would have been ineffective.

While the possibility of electrical forces may be mentioned as an influence, there are no facts known which allow an interpretation in this direction.

During the past two years a considerable number of

experiments have been made in attempts to obtain some definite evidence as to the cause of the rotation. Obviously it would be of interest to maintain a culture of northern forms in the southern hemisphere or a culture of southern forms in the northern hemisphere. Efforts to obtain living cultures from desirable localities, the Falkland Islands, New South Wales, the southern part of South America, etc., have thus far failed. A method, however, was devised by which it seemed theoretically possible to subject northern flagellates to an environment similar to that of the southern hemisphere. A clinostat having a clockwise rotation of fifteen minutes was procured, a circular table ten inches in diameter fitted to this, and the northern half covered so that the revolving table containing slides in excavated recesses would pass into darkness on one side and emerge moving from east to west. Thus the apparent path of the sun so far as the organisms were concerned would be from west to east. The larger unstriated *Euglena* have been used almost entirely in the experiments, inasmuch as it would apparently be impossible to change the direction of rotation in forms like *Euglena spirogyra* Ehrenb., *Phacus pyrum* (Ehrenb.), etc., where the striæ are carinate in structure with an angle almost if not entirely precluding a rotation in the direction opposite to that in which they were accustomed to turn.

While there has been a large amount of data obtained, thus far no evidence shows that either a "reversal" or a "slowing up" of the rotation may be produced in any of the individuals utilized.

Even though it may not be possible to change the direction or the period of rotation in "adult" forms, may not such changes be produced in encysted forms or during a period when gametes are developed. Experiments are yet to be made with individuals in an encysted condition, and with material available it will be possible to utilize gamete-producing forms. That *Euglena* has a sexual cycle was pointed out by the writer nearly ten years ago (Walton, 1909).¹ Certain forms encyst, the cysts subdi-

¹Paper presented at annual meeting of Ohio Academy of Science, 1908.

viding to approximately a 16-cell stage, small flagellate gametes emerge and conjugate. An experiment of this nature involves a discussion of the environmental effect on germ cells as compared with somatic cells, but does not affect the issues with which we are concerned in the present paper.

There are many other questions of interest which arise in a study such as outlined. For instance, what has been the origin of the striæ which are much specialized in many forms, although entirely absent in other forms so far as visibility with the microscope is concerned. The majority of the positive northern forms have "left-handed" striæ, a smaller number have longitudinal striæ, while a considerable number appear to have no striæ. None have been found with "right-handed" striæ. At first one may be inclined to attribute such a character to natural selection, but when one commences to ascertain the value of the character on the basis of progression, rotation and axial angle, such a conclusion seems less certain. There are a few facts that appear evident. First that the development of the striæ has been at a considerably later period than that of the rotation direction. Second that the relative position of the striæ has been largely dependent on the rotation. Third, that the development of the striæ has in many forms proceeded so far that a reversal rotation seems an impossibility.

The presence of a considerable number of other groups which have "left-handed" spirals so far as observation goes, is of interest. The various genera of *Spirochætes*, as well as *Spirulina* and *Arthrospira* among the *Cyanophyceae* (*Cyanophyceæ*) may be mentioned. The twining of plants may, in the final analysis, be attributable to the same cause.

Other related problems are the pendulation theory of Simroth (1912) relative to bipolar distribution, and the tropism theory as outlined by Verworn (1894), in connection with the excitation contraction of the flagellum.

V.

Having indicated some of the difficulties existing along the lines of established research in the efforts to account for the derivation of the fundamental heritable units making up an organism and having presented a series of observations suggesting that a new perspective may be obtained by utilizing methods of attacking the problem somewhat different from those hitherto employed, the particular purpose of the paper is accomplished.

It may be asserted by some that such an attempt at a summary disposal of the existing evidence as to the actual origin of characters represents an unfortunate type of destructive criticism. Furthermore, that the acceptance of the validity of the arguments as to the long predetermined nature of the genes or subgenes, leads us once more in the direction of the somewhat antiquated theory of preformation. It is not impossible that these views are in part justified. Nevertheless it is well within the bounds of propriety to occasionally inquire as to whether the enthusiasm developed for a special discovery has not resulted in too broad an application of its principles. The mutation theory particularly as developed by Morgan is of interest. It is circumscribed at least in part by the phenomena of mendelian inheritance, and it is evident that one should look farther for the facts which may assist in explaining the real origin of the diversity of living things.

If additional studies support the view suggested by the facts here presented, namely, that characters of a physiological nature may be produced by environmental causes, and that these in turn may demand the correlation of morphological characters regardless of the origin of the latter, an important step will have been made in accounting for the primary differentiation of organisms. The later secondary differentiation through the combinations of units which have thus arisen, and which attains its maximum in the complex multicellular animals and plants, offers no particular difficulties in its explanation. Furthermore, such an idea is more in harmony with the paleontological evidence as presented by Osborn (1912)

and others, than one based on the mutational idea, and it is to fossil forms that one must look for the all-important historical record.

Should one propose a hypothesis of an ultimate unit, slightly plastic as to its immediate environment, but subject to the permutations and combinations of a mendelian type, and possessing a definite qualitative condition determined by prolonged environmental action, the picture is not at all so fanciful as some might at first thought insist.

The practical importance of such a viewpoint in its application to the problems of animal and plant breeding lies in the realization that new forms can not be created, but merely new combinations uncovered during the comparatively brief epochs of time which human intelligence has for working out the processes. Thus one returns to genetics.

In summarizing the paper, the following conclusions are suggested:

I. The heritable characters in general which make up an organism arise from preformed units in the nature of genes or subgenes that have been in existence during long geological periods of time. There are at present no criteria available in modern genetics by which an apparently new gene may be distinguished from one long in existence; furthermore, there is doubt as to whether new genes are actually arising in multicellular organisms. The change of a gene in a given direction, whether it be considered as a morphological unit or a chemical condition followed by the return to its original condition, suggests its composition of combinational sub-units, and is an argument against the idea that anything actually new has come into being during its series of so-called mutations. Such a conclusion receives additional support from the presence of apparently identical genes which exist in distinct species of organisms separated during long epochs of time, as well as from the evidence of the non-contamination of genes during diverse environments.

II. The mutations demonstrated by DeVries and others, together with the variations obtained by Castle, are

to be interpreted as a result of the combinations of existing genes. The mutations noted by Morgan and his associates, as evidenced from recurrence and stability, are in the nature of modal fluctuations having no definite cumulative value.

III. The direction of axial rotation in aquatic micro-organisms is best explainable on the basis of the apparent east-west motion of the sun having influenced the movement of the organs of locomotion. Thus the character becomes one acquired from external stimuli, and the persistence of reverse forms in both the northern and southern hemispheres indicates the hereditary nature of the character. Morphological characters, such as the striæ, etc., may arise in a similar manner or through selection. By correlation with the preceding characters, a cumulative and irreversible effect is produced.

IV. The primary factors in evolution are environmental and thus dynamic. The secondary factors of a combinational nature are gradually approaching a limiting maximum value, and are thus becoming static.

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THE POLYCHAETE ANCESTRY OF THE INSECTS.

I. THE EXTERNAL STRUCTURE^{1*}

Two general hypotheses exist relative to the evolution of insects. The one is the Crustacean theory of Müller (1864), Haeckel (1866), Wood-Mason (1879) and others who have maintained that the insects have evolved from Crustacean forms resembling the immature "Zoea" stage where there were three pairs of mouth parts and three pairs of walking appendages corresponding to those found in insects. Modifications of the Crustacean theory have been presented by Handlirsch (1903, etc.), who holds that insects originated from Trilobite ancestors, extinct forms placed as an aberrant group of Crustaceoidea by most systematists, and by Crampton (1918, etc.), who believes that the insects have arisen from forms similar to the Anaspidacea or Mysidacea, small Crustaceans of primitive structure.

The other interpretation is the Campodean theory of Brauer (1868, etc.), which derives the insects from the "Myriapoda" — the Chilopods in the strict sense — and the Onychophoroidea by way of campodeoid forms. This is on the basis of the resemblance of the larvae of many orders to the existing Campodea, a genus of apparently primitive insects belonging to the Thysanura. It is the latter theory that has received the approval of the greater number of systematists who have taken an interest in problems of phylogeny.

That there is quite another interpretation of the origin of insects indicating their descent neither from the Chilopods and the Onychophorans by way of *Campodea*, from the Trilobites, or from the generalized Crustacea, but directly from the Polychaete Annelids, is my decided opinion. This I would term the Polychaete theory.

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Such a view I earlier presented (1913) in a brief discussion concerning the relationship of the parapodium of the Polychaetes to the various areas of the maxilla and other appendages of the insects. The direct derivation of the insects and their allies from such an ancestral type permits the explanation of many characters not easily accounted for on any other basis. While Mayer (1876) advocated the origin of the insects from an annulate worm, which eventually developed ventral and "possibly" dorsal appendages, the implication was that they were newly developed, no suggestion being made of any correspondence between the parapodia and the appendages of the insects. The particular point that Mayer had in mind was in establishing the numerical relationship between the segmental organs of the hypothetical annulate worm consisting of eighteen segments which he assumed to be the ancestor of the insects, and the spiracles taken together with the malpighian tubules of the insect. The conclusions formulated in this connection, however, were so severely criticized by Brauer (1878) that, whatever merit may have existed in the work, it was soon forgotten, except as the historical "Archentomon theory."

The body of the typical insect so far as the evidence is available at the present time consists of twenty-two segments, provided one accepts the existence of a post-mandibular segment bearing the appendages termed the superlinguae. On the basis of the specialization of the segments in groups it has been customary to speak of the cephalic region, the thoracic region and the abdominal region of an insect. In the head region and in the abdominal region, however, a secondary grouping of segments has taken place so that one may with propriety state that an insect is a heterometameric organism formed from five homometameric segmental groups. These groups consist of a prestomal area of three segments, a poststomal area of four segments, a thoracic area of three segments, an abdominal area of seven segments and a caudal area of five segments.

Afforts to arrive at a conclusion as to the structure of a typical segment of the insects acceptable to those inter-

ested in their embryology and morphology have not met with pronounced success. The difficulty is due to the wide diversity of form exhibited by the various orders of insects, the pronounced differentiation of the segmental groups mentioned, together with the inability to agree on the ancestral form from which the insects and their allies, the Symphyloidea, Chilopoidea, Pauropoidea, etc., have arisen.

It is to only one particular phase of the question that I here wish to call attention, namely, the relation of the pleurites and the appendages of the thorax in the insects to the parapodia of the Polychaete Annelids, for it is in the thorax, I am inclined to believe, that one finds the most generalized part of the body so far as the external structure is concerned.

The pleural or lateral part of each thoracic segment consists of two sclerites, the episternum and epimeron, names given by Audouin (1824) in his study of *Dytiscus circumflexus* Fabr., the large water beetle. The origin of these pieces has received little attention, although several explanations have been offered. None of these explanations seems to me to be adequate.

Miall and Denny (1886) suggested that the pleurites as represented by the episternum and epimeron belonged to the lateral area of the segment so far as they were present in the insects, but that in the cockroach they could be considered basal parts of the leg adherent to the thorax. Inasmuch as even the constancy of the two pieces was doubted throughout the insects in general, it is evident that their relation to the base of the leg was looked upon as a specialized condition present in the Blattidae alone. Banks (1893) believed that the two pleurites were to be accounted for through the fusion of two primitive segments, a theory which I myself was earlier (1900) inclined to accept, but which I have long considered untenable. Crampton (1909) suggested that the two areas were "due to a mechanical stress," apparently forgetful of the heresy thus implied in connection with the inheritance of acquired characters. Snodgrass (1909) concluded that the apparent division between the areas re-

sulted from the development of a ridge which was needed to strengthen the pleural area as a support to the leg. The more recent papers devoted to the anatomical structure of the insects by Berlese, Börner, Bugnion, Crampton, Feuerborn, Franz, Göldi, Handlirsch, Heider, Heymons, Imms, MacGillvray, Verhoeff, Weber and others present no new interpretations.

In this paper it is my purpose to call attention to some of the evidence that has induced me to believe that the ancestral type from which the insects and their allies have developed belongs to the Polychaetes, and that intermediate forms will eventually be found in the rocks of the Cambrian or Silurian periods. The well-preserved fauna of the Burgess Shales belonging to the Middle Cambrian of British Columbia, which Walcott has noted in a series of papers, is of decided interest in this connection.

The general argument as to the Polychaete ancestry of the insects may be stated most advantageously in connection with a series of diagrams illustrating the course that evolution has taken, on the basis of the hypothesis advanced.

First, let us consider the structure of the external parts in a typical segment of a living Polychaete. The epidermal cells underlying the integumental covering have secreted a thin protective cuticula with no pronounced folding except in connection with the slightly marked secondary annuli, which at times are marked off by transverse furrows. The latter development of a pronounced segmentation, as it takes place in the various groups descended from the annelids, closely parallels the phyletic development of the notochordal area of the vertebrates, which like the insects and their ancestors have passed from an aquatic to a terrestrial environment.

In the Polychaetes the striking characteristic of the segment is the development upon each side of a lateral fold called the parapodium, which propels the organism through the water and along the sea-bottom. It is attached in a plane nearly perpendicular to the longitudinal axis of the body and consists of a dorsal branch (*nt* =

notopodium) and a ventral branch (*nr* = neuropodium). There is also a dorsal appendage (*dc* = dorsal cirrus), generally developed as a sensory organ, but often forming a gill or more rarely a protective sheath called an elytron. Occasionally other dorsal as well as ventral cirri, usually of smaller size, are present. The dorsal and ventral branches of the parapodium are each supported by a large thick seta (*ac* = aciculum) enclosed in an integumentary sack (*as* = acicular sack), while groups of small setae (*st* = setae) are found at the distal extremities of both the notopodium and neuropodium. The openings of epidermal glands (*ig* = integumentary gland) are scattered over the surface as outlets for the integumentary glands.

There are only a few changes that need to take place in the position and form of the parapodium to convert it into the typical structure of the appendage with the pleurites of the insect. These changes may be indicated by a hypothetical segment intermediate in form between the segment of a typical Polychaete and a typical insect. The parapodium has moved ventrally and forms a plane which in its relation to the axis of the body has turned clockwise nearly forty-five degrees. The lower branch (*nr* = neuropodium) has become large and somewhat elongated as compared with the upper branch (*nt* = notopodium) which remains short and small. The large cirrus (*dc* = dorsal cirrus) retains its development, while any ventral cirri that may have been present have disappeared, unless we assume the retention of small basal cirri which eventually developed as the propterite and pterite (wing). The integumentary glands (*ig* = integumentary gland) assume an increased size and function correlated with the semi-aquatic environment of the organism and become restricted in number.

It is a result quite consistent with the ecological conditions under which many of the Polychaetes existed in marshy areas of the coastal regions. The parapodia would more and more be compelled to support the body of the individual as it moved through the shallow and partially dried pools. The subsequent changes, including that of

aerial respiration through the development of the integumentary pockets as tracheal openings, compared to that which has taken place in *Peripatus* and allied genera, are infinitely less than the changes that have occurred in the descent of the terrestrial vertebrates from aquatic forms.

There are many of the existing Polychaetes in which the structure of the parapodium is closely in accord with the form noted and to which attention will be called in a subsequent part of the present paper.

In turning to a discussion of the external structure of the insects, let us first consider a typical segment with reference primarily to the chitinous skeletal system, for it is here that the relationship with the Polychaetes is most apparent. The segment consists of a dorsal area (*tg* = tergum), a lateral area (*pl* = pleurum) and a ventral area (*st* = sternum). The pleural area is formed from two pieces, of which the one (*eps* = episternum) occupies an anterior ventral position, while the other (*epm* = epimeron) is found on the posterior dorsal part of the pleurum. The appendages are the leg formed from the "coxa," which in turn is composed of an anterior ventral piece (*c* = coxon) and a posterior dorsal piece (*m* = meron), and an evaginated sack-like part of the integument forming the wing (*pt* = pteron). Anterior to the wing is a sclerite (*pr* = propterion) which from its tracheation in certain cases has apparently developed in a way similar to the wing, and which from its constancy in the various orders of insects is here included as a typical part of the segment. A large seta-like appendage (*s* = stylus) is attached to the meron (Machilidae) of the meso- and meta-coxae as well as to the sternal abdominal coxae in many of the Apterygotes. Tillyard advises me that the stylus is segmented in some of the New Zealand Machilids. On the anterior margin of the pleural area is the integumentary opening (*sp* = spiracle) of the trachea.

Many secondary areas have developed in the insects and the groups allied to them. Among these are to be noted the trochantin, ante-coxal piece, subdivisions of the sternum, tergum, episternum, epimeron, propterion, etc. Included in such areas I would place the micro-thorax of

Verhoeff, present not only on the anterior margin of the prothorax but also upon the mesothorax, metathorax and abdominal segments in *Campodea*, *Japyx*, etc., and comparable with similar areas among the Chilopods, as in the Geophilids, etc.

It seems quite obvious that the areas termed "primary" may all be developed from the Polychaete segment, and that the correspondence between the parapodium and the pleural area and basal parts of the leg in the Hexapods indicates a definite relationship. With the parapodium turning on its axis, as indicated in Fig. 2, the proximal part coalescing with the pleural part of the segment and the ventral branch becoming elongated and eventually segmented as it attains a ventral position supporting the body, there is, I feel certain, an explanation of the origin of insects much more satisfactory than any of the theories thus far advanced.

It will be well to discuss somewhat more explicitly certain details in connection with the typical structure of the segment among the insects which bear upon the solution of the problem.

In the suggestion that the basal part of the parapodium has fused with the lateral area of the segment to form the episternum and epimeron, there is really nothing extraordinary. A phyletic development of a similar nature has taken place among other insects, and is particularly noticeable in the family Dytiscidae of the Coleoptera where the metacoxae have the form of expanded plates immovably fused with the sternum. Furthermore, as Haase (1889*b*) has pointed out, each abdominal sternite in the insects represents a pair of coxae that have fused with the sternum so that all trace of the sutural region is lost in most forms.

The division of the pleurum into two areas is not at all confined to the thorax, as some would have us believe, but is to be noted in head region as well as in the abdominal region of many insects. Thus, as I have pointed out (1913), the cardo at the base of the maxilla is composed of two pieces which I there termed the endocardo and the ectocardo on the basis of their apparent correspondence

to the neuropodium and notopodium of the parapodia. These two pieces, I am inclined to believe, represent the episternum and epimeron of the thorax. Even among many of the Chilopods, where there has apparently been a secondary breaking up of the pleura into numerous sclerites, there are still two principal areas demonstrable in each pleurum. Snodgrass (1909) has called attention to this characteristic.

The anterior portion of the coxa, as noted in the accompanying drawings, I have termed the coxon. This is the area which I earlier called the coxa genuina and which has been mentioned by later writers as the eucoxa and the coxa vera. While from certain standpoints it may be considered unfortunate that a priority principle does not enter into anatomical nomenclature in the strict sense that it exists in systematic work, a monomial is here certainly to be preferred to a binomial term, and the word coxon, while open to objections from the classical side as is also the hybrid "eucoxa," possesses the merit of brevity as well as a relatedness to the terms meron and coxa.

Whether an attempt to reduce the confusion of anatomical nomenclature in the insects by presenting new terms for typical generalized structures is justified will remain for future students of the anatomy of insects to decide.

The stylus attached to the meron represents, I am inclined to believe, a dorsal cirrus of the Polychaete parapodium, although two other possibilities present themselves—the one that it is the modified distal area of the notopodium with the terminal tip composed of setae formed from the notopodial aciculum, while the other is that it represents the development of a small setae and is wholly of a secondary character, as Haase (1889*a*) has suggested. The explanation on the basis of a modified notopodial cirrus, which in the different segments has evolved into the maxillary and labial palpi, the mesothoracic and metathoracic styli (Machilidae), the abdominal styli of many Apterygotes and in all probability the tracheal gills of the Ephemeridae, etc., as well as the cerci

of the caudal segments, seems better in accord with the facts as I have already suggested (1913). Furthermore, on such a basis one might explain the paired eversible sacks of the abdominal coxae in many Thysanurans as modified integumentary acicular sacks of the notopodium and neuropodium which in most forms had become reduced to a single sack through fusion or suppression. In the single case known where there are three sacks on a "coxa," some of the sacks if actually separate would have to be accounted for as secondary. These suggestions, however, relate to problems which are beyond the scope of the present paper and for their solution demand a larger background of embryology and morphology than exists at the present time.

The dorsal appendages of the segment as represented in Fig. 3 consist of an evaginated sack forming the wing here designated as the pteron, and the area anterior to its base, which from its constancy throughout the insects both on the mesothorax and on the metathorax is included as a part of the typical segment and termed from its position the propteron. Like the wing it is a hollow segment where structurally large enough to examine and in all probability has similarly developed as an integumentary outpushing. Various names such as pterygodum, parapteron, tegula, squamula, etc., have been applied to it on the different segments in various orders of insects, and it might seem that less confusion would result from the retention of some of these names. While the term pterygodum of Latreille (1820-22) has priority, it was used in a restricted sense for the part at the base of the mesothoracic wing in the Lepidoptera and is rarely noted in the literature relating to the insects. The more familiar term, parapteron, was first used by Audouin (1824) to designate a supposed sclerite which he believed to exist on the anterior margin of the mesepisternum of *Dytiscus circumflexus* Fab. This was merely an area bounded posteriorly by the articulatory ridge at the point of junction with the prothorax, extending in many Coleoptera entirely across the sternum. The transfer of the term to the pieces in front of the wing (propteron) arose

in connection with a footnote attached by Audouin to a translation of a paper by MacLeay (1832), where Audouin suggested that the piece termed the squamula in the Hymenoptera was homologous to the parapteron, which he had noted in *Dytiscus*. Consequently, the term parapteron really has no standing.

The patagium of the prothorax corresponds, I am inclined to believe, to the mesothoracic and metathoracic wing, and similarly possesses a propter. To one familiar with the embryos of certain of the termites as well as with the structure of the prothorax in many fossil insects, the reasons for such a conclusion will seem obvious.

The problem of the origin of the wings still remains a difficult one. That they do not correspond to the tracheal gills seems certain, particularly when one takes into consideration the relative position of the gills, the coxosternum, the pleurites and the metathoracic coxae in a young Ephemerid. The presence of the episternal and epimeral areas, assuming that the parapodium furnishes an interpretation of the origin of the pleurum, might lead to the assumption that a basal notopodial as well as a basal neuropodial cirrus had become changed into an elytral scale-like formation receiving tracheal branches and had given rise to the wing and propter. The structure of *Worthenella cambria* Walcott, a middle Cambrian annelid with the apparent biannulate division of the segments as subsequently figured (Fig. 4), is interesting in this connection. The theory of the origin of the wings, as proposed by Müller (1875), namely, that they are developed from the expansion of the tergum, seems to be untenable, although it is the one which has generally been accepted. Nature has a tendency in evolution to modify existing organs rather than to develop new structures, and I would here consider such a tergal expansion with its new articulation and wing muscles a new structure.

The position of the spiracular openings on the anterior margin of the segment is quite consistent with the parapodial development of the pleurum in that the scattered respiratory pockets of the integument, reduced in number to the paired segmental spiracles with their ramifying

trachea, would tend to occupy a position outside of the parapodial area, either anteriorly or posteriorly, although a secondary migration might occur. This seems to have been the case in some of the Chilopods, notably the Geophilidae. We would here hold to the opinion that the spiracular openings have developed from numerous irregularly disposed integumental glands of the Annelids, as suggested, I believe, by von Kennel, and that the reduction and subsequent segmental arrangement parallels that which has taken place and is still exhibited by existing forms of the Onychophorids.

The development of the transverse segmentation in the parapodium to form the boundaries between the episternum-epimeron and the coxon-meron, as well as the coxon and trochanter, etc., would be correlated with the increasing chitinization of the integument and the need of mechanical assistance from the walking appendages, by the individual. Such seems to have been the history of segmentation among the Vertebrates, Echinoderms, Molluscs, etc., both in the primary and the secondary axes of the body. In other words, the need of pronounced articulatory surfaces is correlated with the development of firm unyielding areas, such as bone, chitin, etc.

The large acicular setae of the neuropodium, often biuncinate distally, furnishes a part that may have readily become transformed into the tarsal claws. Some evidence for such a change is afforded by one of the fossil Polychaetes mentioned later.

Two forms of extinct Polychaete Annelids found by Walcott in the Burgess Shales of the Middle Cambrian Period near Field, British Columbia, are of much interest in connection with the parapodial theory of insect evolution here presented. The specimen to which the name *Worthenella cambria* Walcott was applied in the paper by Walcott (1911) is represented by a single individual about 60 mm. in length, having some forty-six segments. Two striking characteristics are observable, one in the much elongated and apparently bilobed parapodium and the other in the division of the segment into two secondary annular areas, as observed dorsally. The eyes and

the appendages of the head leave no question as to the Polychaete nature of the specimen, although, as Walcott correctly suggests, it belongs to none of the existing families of these annelids.

If we attempt the reconstruction of a typical segment of *Worthenella* on the basis of the available data, there are two alternative hypotheses which one may consider. The one appearing to me as the most consistent interpretation is that of representing the parapodium turned somewhat clockwise on its axis so that the lobular division extending to the dorsal margin of the segment forms a continuation of the boundary separating the secondary annular areas. It is possible, of course, that the annular groove is not related to the biramose division of the parapodium. So far as the outline of the parapodia are concerned, however, they are folded in such a manner that the clockwise turning is indicated. The other interpretation is that the apparent segment represents a fusion of two primitive segments, as in existing Diplopods, and that each lobe is a distinct parapodium. One would not expect such a specialization, however, in an evolutionary stage where the comparatively thin cuticula was quite sufficient to take care of the contortions of the individual. A distinct segmentation followed by segmental fusion belongs to a later phyletic period.

Another form found by Walcott which must also receive consideration in any discussion of the evolution of the insects and the classes allied to the insects is *Aysheaia pedunculata* Walcott also from the Burgess Shales. The parapodia possess terminal "hook-like and straight setae" and closely resemble the ambulatory appendages of existing Onychophorids where the terminal claws have undoubtedly developed from similar hook-like setae. That the tarsal claws of the insects have had a similar development seems extremely probable, although a different line of descent is indicated from that of *Peripatus* and its allies where the appendage has developed from a simple and not from a biramose parapodium.

Among existing Polychaetes the relation of the various areas of the parapodium to the pleurites in the appendage

of the typical insect is illustrated in many forms. Thus in *Eulepis splendida* Treadwell a marine form described from Porto Rico by Treadwell (1901) the neuropodium is much larger than the notopodium, a functional development which as already noted appears to be correlated with the swimming and creeping mode of progression. The dorsal cirrus is prominent and has a position about midway between the basal and distal part of the parapodium.

In *Anthostoma latacapitata* Treadwell, another Polychaete from the same region, a similarly relatively large neuropodium is to be found although the dorsal cirrus is less prominent and relatively more attenuate. Treadwell does not figure the dorsal and ventral aciculus, although their position is to be inferred from the form of the parapodium.

In reference to existing insects a few representative forms taken from different orders will serve to indicate the structural relationship with the typical segment presented in the preceding part of the paper and with the parapodium as illustrated in fossil and in existing Polychaetes.

The Mecoptera, more familiarly known as "scorpion flies," form a small but an extremely interesting phyletic group of insects, as has been pointed out by Tillyard (1920). The mesothorax of *Panorpa communis*, with its anterior episternum-coxon-trochanter-femur area and its posterior epimeron-meron area, presents a structural arrangement easily to be derived from the elongate biramous parapodium of a form not far removed from the Middle Cambrian *Worthenella cambria* Walcott. The general transformation so far as the external integument is concerned is completed through the shortening of the notopodium, the fusion of the base of the notopodium and neuropodium with the lateral part of the segment, and the development of the segmentation of the parapodium, as indicated, form the corresponding segmentation in *Panorpa*. The position of the wings is in accord with their possible derivation from basal cirri, as earlier suggested. Basal cirri are present in many existing Polychaetes, and the small "oval scale-like objects" to which

Walcott (1911) calls attention in the shale surrounding the impression of *Worthenella* may have something to do with the problem. Here again one must await additional material which will throw light upon the subject.

In the Lepidoptera the arrangement of the various areas as illustrated by *Cossus cossus*, one of the large moths, is not far removed from the similar areas as represented by the typical segment of the insects. Two developmental changes are to be noted, the first of which may, however, represent a more primitive condition than exists in other orders, namely, the extreme development of the propter on to form the so-called tegula or parapteron at the base of the mesothoracic wing. The second change exhibits the tendency of the sternum to extend in a posterior lateral direction over the episternum, so that the latter is apparently cut off from the coxon. Such a development is present in many other representatives of the insects.

The Coleoptera, as represented by the metathorax of *Harpalus caliginosus* Fab., do not at a casual glance indicate any pronounced similarity with the arrangement of the sclerites as shown in the typical segment. This is largely due to the dorso-ventral compression of the body with the resulting distortion of the parts. The tendency of the sternum to develop as in the Lepidoptera is particularly noticeable, while the coxal groove for the reception of the femur, particularly characteristic of the metacoxae in the Coleoptera, tends to render the coxon-meron suture obsolete, particularly at the distal end.

Many other representatives of the insects or of the Chilopods or the Symphylids could be noted where the same typical form is indicated. In representatives of the Apterygote insects, like *Machilis*, *Campodea*, *Japyx* or in the Protura, the pleurum-appendage area apparently represents a more specialized development of the parapodium than in the Pterygote insects. To those who have long held to the opinion that the "Thysanurans" are representative forms from which the winged insects have evolved, the implied conclusion will seem a heresy. While it is true that one finds many characters in the Machilid

type which are evidently of a primitive nature and that definite relationships with such Symphylids as *Scolopendrella* and *Scutigerebella* are clearly indicated, it is by no means necessary to insist that the winged insects have developed from such a type. The aerial life which they lead in general has permitted the retention of the cylindrical body and at the same time the parapodial structure. Insects without wings, as well as many of those with wings which need protection by leading a terrestrial life as opposed to an aerial existence, have become much flattened dorso-ventrally and the pleurum correspondingly modified. The pleural regions of the Thysanurans as well as the thoracic regions of the Coleoptera, the Blattidae, etc., illustrate this.

The evidence presented, fragmentary as it is, appears to point definitely to the conclusion that the various groups of insects and their allies have evolved directly from the Polychaete worms, and that the parapodium is the fundamental structure from which not only the appendages and pleurites of the thorax but also the appendages and pleurites of the cephalic and caudal regions have developed. Furthermore, there is evidence in favor of the theory that the wings have originated from basal parapodial appendages quite different in position from those modified as tracheal gills in existing insects. From the systematic side one therefore concludes that the Annelates form a definite phylum, the Annularia, consisting of a series of classes among which are the insects and their allies, and that the Arthropods are wholly an artificial group. We may enumerate these classes as the Pterygotes, the Thysanurans, the Collembolans, the Proturans, the Symphylids, and the Chilopods. More remotely related to the insects are the Diplopods, the Pauropods and the Onychophorans.

In order to eventually establish the course of evolution among the insects paleontological material must be procured. The extremely well-preserved forms, such as *Worthenella*, *Aysheaia*, etc., obtained by Walcott from the Burgess Shales of British Columbia, indicate that it is here that efforts to obtain such material should be made

and that transitional forms between the Polychaetes and the various classes of "Arthropods" are certainly to be found in the Cambrian or Silurian rocks.

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STENOTARSUS BLATCHLEYI, A NEW ENDOMYCHID FROM FLORIDA¹ (COLEOPTERA)*

An Endomychid belonging to the genus *Stenotarsus* quite distinct however from our common *S. hispidus* (Herbst) so widely distributed over the eastern part of the United States, was recently forwarded me for identification by Mr. W. S. Blatchley, of Indianapolis, Indiana. The single specimen collected by Mr. Blatchley was obtained on the west coast of Florida at Dunedin, April 10, 1926, in beating red cedar (*Juniper*).

The species is easily distinguished from *S. hispidus* by having the seven terminal segments of the antennae black, by the uniformly testaceous color of the dorsal side, and by the black areas covering the underside of the metathorax and abdomen. Casey (1916) described *S. solidus* from North Carolina as a new species stating that the "ninth antennal joint (was) distinctly longer than the tenth and not subequal in length as in *hispidus*". All of the many specimens of *S. hispidus* which I have seen however, have the ninth segment of the antennae slightly longer than the tenth segment. Inasmuch as the other characters noted have on the basis of the description only a relatively slight comparative value, the form scarcely merits being retained even as a variety.

The genus *Stenotarsus* is an extremely large one numbering some one hundred and fifty species confined almost entirely to the tropical regions, only a few being found in the temperate zones. The punctuation of the elytra may be utilized to separate the forms into at least three fairly well defined groups, commencing with the well defined striate forms and ending with the irregularly punctuate forms found in North and South America. If we assume with Tillyard that the arrangement of the punctures in

¹Contributions from the Samuel Mather Science Hall. Biology No. 32.

*Reprinted from *Entomological News*, vol. 39 (1928), pp. 216-218.

prominent umbones, entire surface finely and irregularly punctuate; abdomen with first segment equal in length to the three succeeding segments, the fifth longer than the fourth segment, and the narrow sixth longer than the fifth segment.

Length, 4 mm. Diameter, 2.6 mm.

Type in collection of W. S. Blatchley. Taken at Dune-din, Florida.

I take much pleasure in dedicating this species to Mr. Blatchley who has done so much efficient work in promoting the cause of systematic entomology. It is closely related to *S. latipes* Arrow (1920) erroneously identified by Gorham in the *Biologia Centrali-Americana* (1899) as *S. angustulus* Gerstaecker, as pointed out by Arrow. It is to be distinguished however from that species in possessing four basal segments of the antennae which are pale yellow, in its smaller size, and in having the antennae decidedly less than half the length of the body, a characteristic however which differs in the sexes of many species of *Stenotarsus*. In *S. latipes* the two basal segments of the antennae are pale yellow, the third and fourth are pale brown, and the seven distal segments black, while the length of the individual is noted as 5.5 mm. instead of 4 mm. as in *S. blatchleyi*. A careful comparison of the two species would undoubtedly show other distinct differences.

Continued careful collecting in Florida will undoubtedly yield many more subtropical species of insects particularly among the minute forms so often overlooked by the average individual interested in entomological pursuits. We should thus be quite appreciative of the results obtained by Mr. Blatchley in helping to demonstrate the value of keen observation in connection with the fauna and flora of Florida.

the form of striae represents a more primitive condition, so far as the Coleoptera are concerned, than the irregular arrangement, the trend of migration in the group is clearly indicated.

The two species found within the limits of the United States and Canada may be easily separated by the following characters.

Table of Species.

Antennae with six distal segments black; disk of each elytron black with a narrow pale yellow border sometimes obsolete along the suture; underside uniformly pale yellow. *S. hispidus.*

Antennae with seven distal segments black; dorsal surface of the body uniformly pale yellow except the eyes; abdomen and metathorax beneath with large black central area. *S. blatchleyi.*

Stenotarsus blatchleyi, n. sp.

Uniformly light yellow in color with the exception of the seven distal segments of the antennae, the eyes, and a central area covering the greater part of the underside of the abdomen and the metathorax, black; clothed with long yellowish hairs.

Form elongately oval, the elytra gradually narrowed behind so that an acuminate appearance is presented; legs comparatively short; antennae extending slightly beyond the posterior margin of the pronotum, the first segment somewhat elongate, second globose, third to seventh segments slightly increasing in length, the sixth and seventh segments distinctly longer than broad, the eighth segment globose, and the ninth, tenth and eleventh segments forming a club the length of which is approximately equal to the length of segments three to eight inclusive; distal segment elongately oval and acuminate at tip.

Pronotum transverse with posterior angles slightly acute, decidedly narrowed anteriorly, central area convex, marginal lines distinct, longitudinal sulci scarcely attaining the middle, slightly convergent anteriorly, fine basal sulcus almost in contact with the posterior margin.

Scutellum punctuate, broadly triangular; elytra with

THE WORD CARIBOU*

Studies relating to the historical origin of words may be quite as interesting and oftentimes more profitable than monographic reviews dealing in wearisome detail with the phyletic development of some organism concerning which the most of us know little and care less. Very recently in reading the journal of that intrepid explorer, Sir Alexander Mackenzie, describing a canoe voyage from Lake Athabasca to the Arctic Ocean down the great river now bearing his name¹ I was impressed by a paragraph and the possible significance it might have in throwing light upon the origin of the word "caribou." This is perfunctorily recorded in various dictionaries as being either of French Canadian² or of Indian³ origin without further comment, although some editions of Webster state that it is derived from the Indian word meaning "pawer" without noting the specific word.

Mackenzie, while making the trip in 1787, writes in his journal as follows (p. 209): "We saw some rein-deer on one of the islands (Great Slave Lake) and our hunters killed five and two smaller ones . . . This island was accordingly named Isle de Carreboeuf." While it is not clear from the context as to the size a reindeer must attain before possessing a numerical value, the implication that "caribou" is derived from *carre* signifying four, and *boeuf* indicating bovine or ox, is fully apparent and seems to have escaped the attention of lexicographers. In the reindeer horns are possessed by both sexes and the number four may well refer to the fact that each horn has a large horizontal as well as perpendicular prong, so that there

¹"Voyages from Montreal through the Countries of North America," London, 1801, Allerton edition.

²Webster's Dictionary—some editions; Standard Dictionary; Lettré, Dictionnaire Langue Français.

³Murray, New English Dictionary; Webster's Dictionary; Century Dictionary; Hatzfeld, Dictionnaire Langue Français.

*Reprinted from *Science*, vol. 68 (1928), pp. 352-353.

are four principal prongs. Some editions of Webster give "carribou" as a variant spelling.

It is of course not impossible that we are dealing with a word originating in a tribe of northern Indians and that Mackenzie made an error in suggesting its French origin. The Algonquin Indians as well as their relatives of the Great Slave and Athabasca regions, however, use the word "Atick," while the Esquimaux use the word "tuktu" for reindeer. Even should the word "caribou" appear in some of the Indian dialects, one would still be inclined to suspect its French paternity through contact with early traders.

Among the historical papers of the seventeenth or the latter part of the eighteenth centuries, particularly those relating to the fur trade, references should be found which will remove any existing doubts. In the meantime we may assume the following derivation: Caribou < carribou < Fr. *carre* < *quarre* < Lat. *quadri* = *quattour*, four + Fr. *boeuf* < Lat. *bos* < (*bov*) < Gk. *boûs*, ox, the four-horned ox.

DETERMINING THE AVERAGE FIBER LENGTH IN WOOL YARNS*

In studies relating to the standardization of fabricated wools, one of the problems is that of determining the average fiber length in yarns forming the material. Inasmuch as the methods in use are far from satisfactory, a new method based on a simple principle, namely, the number of fiber ends in a given section of a sample, is presented.

Since the number of ends is twice the number of fibers, one obtains the aggregate length of all fibers, assuming them continuous, and divides the result by one half the number of ends. The latter determination is based on an average from a series of counts in random cross-sections under a microscope. Thus knowing the length (s) of any sample, the number (n) of fibers in a cross-section and the average number of ends (e), the formula for average length (l_1) is expressed by a simple equation (1)

$$l_1 = 2 (sn/e) \text{(1)}$$

applicable to any textile thread of yarn composed of ordinary fibers.

There are several peculiarities in yarns, however, which need consideration, one the irregular arrangement of fibers, particularly in woolens, the other the twisting of the yarn in spinning. While fibers composing a worsted are relatively long and straight, those in a woolen yarn are short and irregular in position. This irregularity usually presents some recurved fibers, particularly at the surface, and the number thus added to a cross-section gives results approximating those obtained for worsteds. In connection with the process of spinning, one may consider the fibers as helices with an angle (θ) measuring the pitch. This presents two possibilities.

If the axial fibers are not under a longitudinal tension

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due to spinning, one may substitute $s/\sin\theta$ for (s) in equation (1) and the average length (1_2) is indicated by equation (2).

$$1_2 = 2 (s/\sin \theta) n/e \text{ -----} (2)$$

If, however, the axial fibers are under tension, a different mathematical treatment is needed, since the lengths of the assumed continuous fibers will vary from the lengths of the axial fibers (s) to those of the peripheral fibers $(s/\sin\theta)$, the distribution about the axis corresponding to the square of the radius. Using (R) for the radius of the segment and (r) for the varying radii, the total length of all helices (Σh) is exhibited by equation (3).

$$\Sigma h = (sn/\pi R^3 \tan \theta) \int_0^R 2\pi r \sqrt{r^2 + R^2 \tan^2 \theta} dr \text{ -----} (3)$$

and the average length (1_3) is shown in equation (4).

$$1_3 = 4 sn \cdot \tan^2 \theta (\csc^3 \theta - 1) / 3e \text{ -----} (4)$$

The differences in the values obtained by (1), (2) and (4) are relatively small and experiments with fibers of known length are closely in agreement with the theoretical values. Any factor for average fiber length will need a modifier, probably of an exponential nature, determined in connection with subsequent experimental work, since the increase in strength of yarns will not continue to be proportionate to the increase in fiber length.

The development of standards for materials along the lines suggested, presenting something more than arbitrary objective tests, is decidedly desirable under our present economic system. Such studies are now in progress.

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