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CONTENTS.

CORRECTIONS.

P. 107, line 5.— For an, read any.

P. 118, line 6.— For bedt, read bent.

P. 125, line 5.— For were, read was.

Line 10.— For relationship, read relationships.

Note.— For November 8, read 18.

P. 127.— On the authority of Mr. Jackson, it should be said that Mr. Darwin did not make the testamentary provision he had intended, for the publication of the Index Kewensis, but his well-known purpose was nevertheless carried out by Mrs. Darwin and her family.

P. 132, line 10.— For Haberland, read Haberlandt.

P. 139, line 22.— For Haberland, read Hildebrand.

P. 150.— For Puguax, read Pugnax.

P. 211, line 20, 213, 3rd line from bottom.— For Concardium, read Conocardium.

Transactions of The Academy of Science of St. Louis.

VOL. XI. No. 1.

A REVISION OF THE LIMNAEAS OF NORTHERN ILLINOIS.

FRANK COLLINS BAKER.

Issued January 16, 1901.

A REVISION OF THE LIMNAEAS OF NORTHERN ILLINOIS.*

FRANK COLLINS BAKER.

In the number of the Nautilus of June last the writer presented a revision of the Physae of the northeastern part of Illinois, and in the present paper the genus Limnaea is discussed in the same manner. The Limnaeids seem to be better understood than the Physae, although far too many names have been given to them, founded for the most part on very trivial characters.

The collection of Limnaea in the Chicago Academy of Sciences is very rich, especially in the fauna of the Mississippi Valley, and enough material has been at hand to satisfactorily determine the specific standing of a number of names. The writer may be thought to have been too radical in the matter of synonymy, but the conclusions reached seem to be borne out by the natural divisions of the group.

My thanks are due to the following persons, either for specimens, notes or suggestions: Mr. Bryant Walker, Detroit, Michigan; Mr. J. H. Handwerk, Joliet, Illinois; Messrs. T. Jensen, F. M. Woodruff, and Prof. W. K. Higley, of Chicago; and to the Natural History Survey of the Chicago Academy of Science for the loan of the cuts in the text of the present article.

KEY TO SPECIES OF LIMNAEA.

A. Shell 50 to 60 mill. in length.
  a. Aperture and spire about equal in length, the former much expanded. *stagnalis.*

B. Shell 30 to 40 mill. in length.
  a. Spire attenuated, longer than aperture, the latter strongly reflexed; surface very rarely malleated. *reflexa.*
  b. Spire and aperture about equal in length; surface nearly always heavily malleated; shell wider in proportion to length than (a). *palustris.*

* Presented, and read by title, before The Academy of Science of St. Louis, December 17, 1900.

C. Shell 10 to 20 mill. in length.
  a. Surface marked with distinct, impressed spiral lines.
    1. Spire longer than aperture, shell attenuated. *caperata.*
    2. Spire equal to aperture, shell globose in form. *cubensis.*
    3. Spire half the length of the aperture. *columella.*
  b. Surface without distinct spiral lines.
    1. Spire equal to or longer than aperture.
      † Spire short conic, aperture roundly ovate, not produced. *humilis.*
      †† Spire long and pointed, aperture long-ovate, produced. *desidiosa.*
    2. Spire shorter than aperture.
      † Spire bluntly rounded, shell very globose. *catascopium.**

A recent study of numerous species of this genus has convinced the writer that some classification other than the one in use must be found. The present grouping by shell characters is totally unsatisfactory on account of the extreme variability of the individuals. For example, different forms of *L. emarginata* Say var. *mighelsi* Binney, recently examined, can be placed in all of the so-called subgenera usually recognized (*Radix*, *Bulimnea*, *Limnophysa*, etc.) and in fact the typical *emarginata* is typical of *Limnophysa*, and the variety *mighelsi* of *Radix;* all of the intermediate forms occur and absolutely connect the extremes. In view of this fact the writer has discarded all subgenera, using simply the generic term *Limnaea*. Some divisions of value undoubtedly *will* be found when all of the species are examined anatomically, for the genitalia, radula, etc. There is abundant work in this line for a naturalist having the time and material at his command.

1. Limnaea columella Say.

Pl. I. f. 13.

Limnaea columella Say, Journ. Phil. Acad. **1** : 14. 1817.
Limnaea navicula Valenciennes, Rec. d'Obs. **2** : 251. 1833.
Limnaea chalybea Gould, Am. Journ. Sci. i. **38** : 196. 1840. (Variety.)
Limnaea acuminata Adams, l. c. **39** : 374. 1840.
Limnaea strigosa Lea, Proc. Amer. Phil. Soc. **2** : 33. 1841.
Limnaea coarctata Lea, l. c. p. 33. 1841.
Limnaea casta Lea, l. c. p. 33. 1841. (Variety.)
Succinea pellucida, Lea, Proc. Phil. Acad. **1864** : 109.
Limnaea columellaris Adams, Amer. Journ. Sci. i. **36** : 392, absq. descr.
Limnaea succiniformis Adams, ms. teste Haldeman.

Shell: Ovate, somewhat pointed, thin, fragile, transparent; color light greenish or yellowish horn; surface shining, cov-

* The long spiral form is not found in this region.

ered with rather coarse growth lines, and encircled by impressed spiral lines; whorls 4, rounded, rapidly enlarging, the last one three times the size of the rest of the shell; spire sharply conic, rather short; apex small, very dark brown; sutures impressed, aperture ovate, dilated, expanded at the lower part; the aperture varies from long and narrow to wide and somewhat expanded; peristome thin, acute; columella narrow, twisted; terminations of peristome connected by a thin callus; umbilicus generally closed but sometimes very narrowly perforate where the callus is not fully developed; the columella is so thin and narrow that a view may be taken from the base nearly to the apex, as in *Succinea retusa*.

Length 16.00; width 8.50; aperture length 11.40; width 6.00 mill. (10440.)
" 14.00; " 7.75; " " 9.50; " 5.60 " (10440.)

Animal: Almost transparent, with a short, wide foot, bluntly rounded behind; head separated from foot by a constriction, wide, bifurcated; tentacles short, thick, triangular, transparent; eyes black, situated on small prominences at the inner base of the tentacles; color dirty white, darker on the body which is covered with white spots, seen through the transparent shell; edge of mantle transparent, simple; head above lilac-tinted; respiratory orifice on right side of body, near the junction of the upper part of the columella with the body whorl; the head is not much in advance of the edge of the shell when the animal is in motion; the aperture appears much too large for the shell. The heart is situated on the left side of the animal, as in *desidiosa*. The pulsations are rather irregular, three or four being quick, then followed by a pause; they vary from 53 to 60 per minute. Length of foot 8.00; width 5.50 mill.

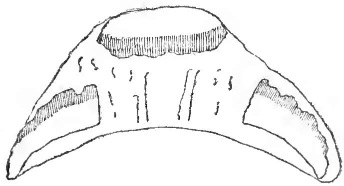

FIG. 1. Jaws of *Limnaea columella* Say.

Jaws: Three, the median elliptical, smooth, the lateral jaws irregular; finely striated; cutting edges brownish black, shading into yellowish brown as the base of the cartilage is reached (*f. 1*).

Radula formula: $\frac{25}{4+}+\frac{1}{3}+\frac{9}{2}+\frac{1}{1}+\frac{9}{2}+\frac{1}{3}+\frac{25}{4+}$ (35 — 1 — 35): central tooth as in the genus; lateral teeth with a quadrate base of attachment; reflection long and rather wide, reaching below the base of attachment, bicuspid, the inner cusp very large and long, the outer cusp small and sharp; the tenth tooth is trifid and connects the lateral and marginal teeth; marginal teeth much longer than wide, generally four-cuspid, the inner cusp placed about midway of the reflection, the other three placed at the distal end; there are generally several small denticles on the upper inner edge of the reflection; the outer marginals have all the cusps placed at the distal end and the margins are simple (*f. 2*).

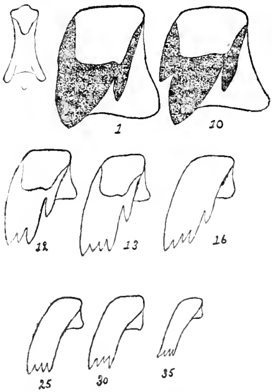

FIG. 2. Radula of *Limnaea columella* Say. C, central tooth; 1, first lateral; 10, first marginal; 12, 13, 16, typical marginals; 25, 30, 35, typical outer marginals.

Distribution: New England to Iowa, Canada to Georgia; Tepic, New Mexico.*

Geological Distribution: Pleistocene; Loess.

Habitat: Found abundantly in small ponds and creeks where the water is more or less stagnant. Particularly fond of a locality where lily pads are in abundance.

Remarks: This species is very variable in the shape of its aperture, and several distinct species have been made from these variations, which will stand simply as varieties. It is very frequently taken for *Succinea* and the shell bears a very strong resemblance to that genus. The animal, however, is quite different, and shows that it is a genuine *Limnaea*. The raised spiral lines are very beautiful, and different from those of any other *Limnaea* in our area. So far as known it has only been collected in the greenhouse and lily ponds in Lincoln Park.

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* Vide J. G. Cooper, Proc. Cal. Acad. Sci. ii. **51**: 167. 1895.

2. Limnaea catascopium Say.

Pl. I. f. 9.

Limnaea catascopium Say, Nich. Encycl. ed. 1. *pl. 11. f. 3.* 1816.
Limnaea virginiana Lamarck, An. sans Vert. ed. 1. **6**: 160. 1822.
Limnaea cornea Vallenciennes, Recueil d'Observ. Zool. etc. **2**: 251. 1833.
Limnaea sericata Ziegler, Rossmässler Iconog. **1**: 98. 1837.

Shell: Thin, globosely ovate, inflated; color light horn to blackish; surface dull to shining, lines of growth numerous, fine, crowded, wavy; apex frequently eroded; whorls 5, rounded, inflated, the last very large and inflated; spire sharp to obtuse, conic; sutures slightly impressed; aperture roundly ovate, large, from half to three fourths the length of the entire shell, rounded below, somewhat narrowed above; peristome thin, sharp, thickened by a light callus just within the edge, the callus whitish; columella oblique, with a heavy plait across the middle; the lower part of the columella has a flexure caused by the heavy plait; the lower part of the peristome and the whole of the columella are covered by a heavy coating of white, testaceous material, which is reflected over the umbilicus, completely closing it.

Length	13.50;	breadth	8.75;	aperture	length	8.00;	breadth	5.00	mill.	(8388.)
"	14 50;	"	9.50;	"	"	9.50;	"	5.50	"	(8388.)
"	14.00;	"	9.00;	"	"	8.75;	"	5.00	"	(8388.)

Animal, jaw and *radula* not examined.

Distribution: New England to Utah, British America to Virginia.

Geological Distribution: Pleistocene.

Habitat: In the larger lakes and rivers, attached to sticks, stones and various debris.

Remarks: Catascopium is readily distinguished by its large, rounded aperture and swollen whorls. The height of the spire varies, in some specimens being one-half the length of the aperture while in others they are about equal in height. The long spiral form has not been collected in the area under consideration, and is much more common in New York State than in the west.

2a. Limnaea catascopium pinguis Say.

Pl. I. f. 12.

Limnaea pinguis, Say, Journ. Phil. Acad. **5**: 123. 1825.

Shell: Differing from typical *catascopium* in being more globose, having a large aperture, a short, stumpy spire and a very large body whorl; the umbilicus is open and deep.

Length	10.50;	width	7.50;	aperture	length	8.00;	width	4.50	mill.
"	10 50;	"	7.00;	"	"	6.75;	"	4.50	"
"	12.00;	"	9.00;	"	"	8.50;	"	5.50	"
"	8.00;	"	5.25;	"	"	6.00;	"	3.50	"
"	8.00;	"	5.75;	"	"	5.75;	"	3.50	"
"	7.75;	"	6.00;	"	"	6.25;	"	4.75	"

Animal: Not differing from the typical form.

Radula and *Jaw:* Not examined.

Distribution: Apparently the same as the typical form.

Geological Distribution: Pleistocene.

Habitat: Same as *catascopium.*

Remarks: This distinct little variety has been found very recently by Mr. F. M. Woodruff at Miller's, Indiana, in the debris thrown up by the lake, where it may be collected by thousands. *Pinguis* is distinguished by its very short spire, swollen body whorl and large aperture. The specimens from Miller's are all yellowish or corneous in color although all the specimens from this locality were dead beach shells. The surface is frequently strongly malleated. Thus far it has been found only at Miller's, Indiana, on the Lake shore in Chicago at Oak street, and at Edgewater.

3. Limnaea desidiosa Say.

Pl. I. f. 8.

Limnaea desidiosa Say, Journ. Phil. Acad. **2** : 169. 1821.
Limnaea modicella Say, Journ. Phil. Acad. **5** : 122. 1825.
Limnaea acuta Lea, Trans. Amer. Phil. Soc. **5** : 114. *pl. xix. f. 81.* 1837.
Limnaea philadelphica Lea, Proc. Amer. Phil. Soc. **2** : 32. 1841.
Limnaea plica Lea, Proc. Amer. Phil. Soc. **2** : 33. 1841.
Limnaea rustica Lea, l. c. p. 33. 1841.
Limnaea planulata Lea, l. c. p. 33. 1841.
Limnaea jamesii Lea, Proc. Phil. Acad. **1864** : 113.
Limnaea decampi L. H. Streng, The Nautilus. **9** : 123. 1896. (Variety.?)

Shell: Subconic, pointed, oblong, rather thin, sometimes inflated; color light or dark horn; surface shining, covered with numerous crowded, fine lines of growth which can scarcely be discerned on the apex; whorls 5, somewhat shouldered in some forms, the shoulder being near the suture; the last whorl is very large, half the length of the entire shell; each whorl is double the size of the one preceding; spire sharply conical; sutures very deeply indented; aperture elongately-ovate, somewhat expanded; peristome thin, acute; columella thickened by a testaceous deposit, and bearing a heavy plait across the middle; the columella is reflected at the lower end, the reflection almost covering the umbilicus, which is narrowly open; the umbilical region is somewhat indented. The surface is sometimes broken up by coarse, spiral semi-ridges, with facets forming a somewhat reticulated surface.

Length	12.00;	width	6.00;	aperture	length	6.00;	width	3.00	mill.	(8457.)
"	12.00;	"	5.25;	"	"	6.00;	"	3.50	"	(8457.)
"	10.00;	"	4.00;	"	"	5.50;	"	2.50	"	(8457.)
"	8.75;	"	5.00;	"	"	4.50;	"	2.50	"	(8457.)
"	13.00;	"	5.75;	"	"	7.50;	"	4.00	"	(8468.)

Animal (*f. 3*, after Binney): With a very small, more or less oblong foot, when viewed from the base, the anterior and posterior borders rounded; color dark gray or blackish, lighter below; the whole surface is dotted with whitish, which is specially noticeable about the eyes; tentacles triangular, flat, short, more or less transparent; the black eyes are placed on prominences at the inner base of the tentacles; respiratory orifice on the right side, near the angle of the peristome and body whorl. Length of foot 5.00, width 3.00 mill. The heart is situated near the umbilicus and the pulsations are very rapid; the writer counted 150 to 155 per minute.

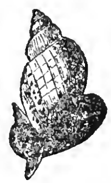


FIG. 3. Animal of *Limnaea desidiosa* Say. (Binney, *f. 25.*)

Jaw: As usual.

Radula formula: $\frac{30}{4+} + \frac{9}{3} + \frac{7}{2} + \frac{1}{1} + \frac{7}{2} + \frac{9}{3} + \frac{30}{4+}$ (46 — 1 — 46): central tooth as usual; lateral teeth with a subquadrate base of attachment, the reflection very broad, bicuspid, the inner cusp long, reaching below the lower margin of the base of attachment, the side cusps smaller; the 8 to 16 laterals are tricuspid, the inner cusp very small; these may be called intermediate marginals; marginals at first (17 to 20) modified laterals, with a long, bifid inner cusp and two very short outer cusps; rest of marginals long and narrow, serrated, generally three short cusps at the distal end and two short cusps at the outer side; these latter disappear toward the outer part of the membrane (28–45): all have cutting points, especially well developed on the laterals and first marginals (*f. 4*).

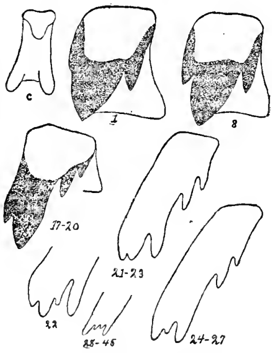


FIG. 4. Radula of *Limnaea desidiosa* Say. C, central tooth; 1, first lateral; 1–8, laterals; 17–20, modified marginals; 21–45, various types of marginals.

Distribution: New England to Iowa, Canada, Manitoba and California, south to Virginia, Kentucky and New Mexico.

Geological Distribution: Pleistocene; Loess.

Habitat: In small bodies of water, clinging to submerged stones and sticks. It occasionally inhabits the large rivers. Prefers still water, and has been dredged in Lake Superior at a depth of 8 to 13 fathoms.

Remarks. This species is subject to some little variation, and numerous names have been given to the forms.* In the main, however, it may be recognized by its long, pointed apex, and elongately-ovate aperture. It approaches *L. humilis* in some of its forms, but that species always has a shorter, more obtuse spire and a more rounded aperture. The lower part of the aperture in the latter species is not produced as in *desidiosa*. When in motion the animal is slow and deliberate; the shell is pulled forward by a series of jerks. This is a very common *Limnaea* and is found in all parts of the area. Found fossil in sand banks on the lake shore north of Graceland avenue.

* It is evident from study of present material and the original figures and descriptions, that several other so-called species will have to become synonyms of *desidosa: L. obrussa* Say and *L. fusiformis* Lea, may be considered doubtful species.

4. Limnaea humilis Say.

Pl. I. f. 14.

Limnaea humilis Say, Jour. Phil. Acad. **2** : 378. 1822.
Limnaea parva Lea, Proc. Amer. Phil. Soc. **2** : 33. 1841.
Limnaea curta Lea, l. c. p. 33. 1841.
Limnaea exigua Lea, l. c. p. 33. 1841.
Limnaea griffithiana Lea, l. c. p. 33. 1841.
Limnaea linsleyi De Kay, Moll. of New York. 72. *pl. iv. f. 74.* 1843.
Limnaea lecontii Lea, Proc. Phil. Acad. **1864** : 113.

Shell: Thin, transparent to translucent, ovate-conic; color light horn, sometimes reddish; surface shining, covered with numerous crowded lines of growth, which are not much elevated and which disappear on the apex; whorls 5, well-rounded, the last being a trifle longer than the spire in most specimens; spire obtusely conic; sutures impressed, sometimes indented; aperture oblong-ovate, somewhat expanded, narrowed at the upper part, generally a little longer than the spire; peristome thin, acute; columella oblique, covered with a thin testaceous deposit; the columella is reflected along the lower third, the reflection nearly covering the umbilicus which is narrowly open.

Length 8.50;	width 4 00;	aperture length 4.50;	width 2.75 mill.	(10488.)
" 8.00;	" 4.50;	" " 4.50;	" 2.25 "	(10488.)
" 7.25;	" 3.50;	" " 3.75;	" 2.00 "	(10488.)

Animal: In general form similar to *desidiosa;* color light brown or blackish, lighter on the foot, translucent about the edges of the body. Heart situated as in the last species, pulsations regular, 140–146 per minute.

Jaw: As usual.

Radula formula: $\frac{12}{4+} + \frac{4}{3} + \frac{6}{2} + \frac{1}{1} + \frac{6}{2} + \frac{4}{3} + \frac{12}{4+}$ (22—1—22); central tooth as usual; lateral teeth bicuspid, the inner cusp very long and wide, bifid, the outer cusp smaller; marginal teeth long and narrow, the distal end four-cuspid, and two small denticles on the center of the outer margin (*f.* 5). A second example gave 15 — 1 — 15 teeth with six laterals. This latter was probably an incom-

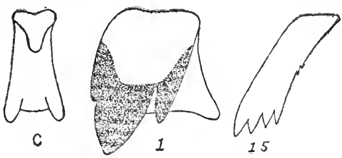


Fig. 5. Radula of *Limnaea humilis* Say. C, central tooth; 1, first lateral; 15, ninth marginal.

plete membrane, as several examinations gave the result recorded above.

Distribution: New England to California, Canada to Georgia, Texas and New Mexico.

Geological Distribution: Pleistocene; Loess.

Habitat: Similar to that of *desidiosa*. It seems to prefer the under side of boards, sticks and lily pads.

Remarks: As remarked under the last species, *humilis* is closely related to *desidiosa*. It is always smaller (about one half) is never malleated, and the spire is shorter and more conic and the aperture more rounded. This is one of our most abundant species and may be found by the hundred in any small pond or ditch, attached to submerged sticks, stones or vegetation. It is, like all the Limnaeids, very sociable and is always found in communities. *L. desidiosa*, *caperata* and *palustris* are almost always found associated with this species. It is as frequently out of water as in it, and this fact has led some conchologists to identify it as *Pomatiopsis*. Not long ago a number of specimens were given to the Academy by a gentleman who said they were found in wet moss but not in the water at all. He thought, from this fact, that they must certainly be a land mollusk. The writer has had this species crawl over his desk like some of the land snails, which fact is true, in a lesser degree, of *L. caperata* and *desid iosa*. It is very abundant and universally distributed.

5. Limnaea caperata Say.

Pl. I. f. 11.

Limnaea caperata Say, New Harm. Diss. 2 : 230. 1829.

Shell: Ovately elongate, rather solid, translucent; color yellowish horn to brown, sometimes black; surface shining or dull; lines of growth numerous and very fine; shell encircled by numerous irregular, impressed spiral lines, which give the shell a somewhat latticed appearance; these spiral lines are placed on the epidermis and may be rubbed off with a brush; whorls 5–6, convex, the last less than half the length of the shell; spire long, somewhat acute; sutures very heavily impressed; aperture ovate, its termination more or less rounded, frequently reddish or purplish; peristome thin, sharp; columella strong, white; reflected so as to cover the umbilicus, there is a small fold crossing the center of the columella; umbilicus small, narrow, deep, covered by the reflected columella.

Length	12.00;	width	5.50;	aperture	length	5.50;	width	3.00	mill.	(10656.)
"	10.50;	"	5.00;	"	"	5.00;	"	2.50	"	(10656.)
"	9.00;	"	4.50;	"	"	4.00;	"	2.50	"	(10656.)
"	11.00;	"	5.50;	"	"	5.50;	"	3.00	"	(10437.)
"	13.00;	"	6.00;	"	"	6.00;	"	3.50	"	(12337.)
"	15.50;	"	7.00;	"	"	7.50;	"	4.00	"	(12687.)

Animal: Black or bluish black, lighter below and minutely flecked with small whitish dots, which are scarcely visible, except on the top of the head; head distinct; tentacle short, flat, triangular; foot short and wide, 8 mill. long and 3 mill. wide. Heart placed a trifle below the center of the columella, the pulsations ranging from 129 to 133, somewhat irregular.

Jaw: As usual.

Radula formula: $\frac{23}{4+}+\frac{2}{3}+\frac{7}{2}+\frac{1}{1}+\frac{7}{2}+\frac{2}{3}+\frac{23}{4+}$ (32 — 1 — 32): central tooth as usual; lateral teeth with a subquadrate base of attachment, the reflection longer than wide and bicuspid; the inner cusp very large, the outer cusp short; the 8–10 teeth are modified from laterals to marginals by the bifurcation of the inner cusp, and the splitting up of the upper part of the outer cusp into small denticles; the tenth tooth is trifid on the inner cusp and the eleventh and all that follow are of the usual form (*f. 6*).

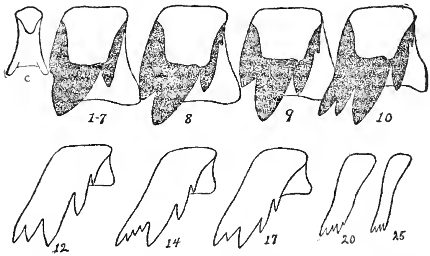


FIG. 6. Radula of *Limnaea caperata* Say. C, central tooth; 1–7, lateral teeth; 8–9, modified marginal teeth; 10, first true marginal; 12, 14, 17, intermediate marginals; 20–25, outer marginals.

Distribution: New England to California and Hudson Bay to Louisiana.

Geological Distribution: Pleistocene; Loess.

Habitat: Found in small colonies in ditches and clear patches of swamp. It prefers submerged pieces of wood.

Remarks: This species is distinguished by its heavy spiral lines and long, acute spire. The animal is very rapid and decisive in its movements. Several specimens, kept together in captivity, ate holes in each other's shell for the lime for their own shells. This was at first attributed to cannibalism, but upon investigation no foundation for this supposition was found. It is quite abundant and is one of the neatest Limnaeids found in this area. An egg mass of this species was laid March 18, 1897. It contained 45 eggs, distinctly nucleated, and in a jelly-like mass measuring 11 by 2 mill.

On March 18th a second egg mass was laid and on the 19th three more masses. On the 22d three individuals were seen in coitu, each one endeavoring to play the active part. Of the five egg masses laid each contained the following number of eggs: 42, 42, 35, 45, 28. The eggs were spherical in shape and very distinctly nucleated. One set of eggs was laid the morning of the 19th and at noon of the 20th embryos were seen slowly rotating about, propelled by numerous cilia. The writer regrets that through some accident which occurred while moving from one house to another, the eggs became lost, so that he is unable to record any exact observations on the embryology of *caperata.*

This species is closely related to *cubensis* and might, perhaps, more properly be made a variety of that form than a distinct species. The spire in *caperata* is long and somewhat pointed and the aperture is much shorter than the spire. In *cubensis* the spire is short and conic and about equal to the aperture in length. *Caperata* is found universally distributed through the area.

6. Limnaea cubensis Pfeiffer.

Pl. I. f. 10.

Limnaea cubensis Pfeiffer in Weigmann's Archiv. für Natur. **1839** : 354.

Limnaea umbilicata Adams, Amer. Jour. Sc. i. **39** : 374. 1840.

Limnaea techella Haldeman, Amer. Jour. Conch. **3** : 194. *pl. vi. f. 4.* 1867.

Shell: Ovate, solid, translucent; color yellowish or brownish horn; surface shining, growth lines fine and numerous; shell encircled by impressed spiral lines; whorls 5, very convex, the last whorl inflated, occupying from one half to three fifths of the total length of the shell; spire short, obtuse, conic; sutures much impressed; aperture roundly ovate, $\frac{1}{2}$ to $\frac{3}{5}$ the length of the shell, the terminations rounded; peristome thin, sharp, thickened inside by a reddish deposit; columella strong, reflected over the narrowly open umbilicus; columella with a small fold.

Length	10.00;	width	5.00;	aperture	length	5.50;	width	2.75	mill.	(10655.)
"	6.00;	"	4.00;	"	"	3.50;	"	2.00	"	(10655.)
"	6.75;	"	4.00;	"	"	4.00;	"	2.00	"	(10492.)
"	11.25;	"	6.50;	"	"	6.50;	"	3.50	"	(12475.)
"	14.00;	"	6.00;	"	"	7.00;	"	3.50	"	(12686.)

Animal: Similar to that of *caperata*.

Jaw: As usual, striated.

Radula formula: $\frac{23}{5+} + \frac{2}{4} + \frac{1}{3} + \frac{4}{2} + \frac{1}{1} + \frac{4}{2} + \frac{1}{3} + \frac{2}{4} + \frac{23}{5+}$ (30 — 1 — 30): central tooth as usual; first four laterals with a quadrate base of attachment, about as wide as high; reflection bicuspid, the inner cusp very large, the outer cusp smaller; fifth to seventh transitory, the inner cusp becoming split up into two cusps and a smaller cusp appearing on the outer side of the outer cusp; eighth, and all after true marginals, long and narrow, with from five to seven cusps; at first two of the cusps are situated some distance up the outer margin of the cusp; but finally (20) they appear only on the distal end (*f.* 7).

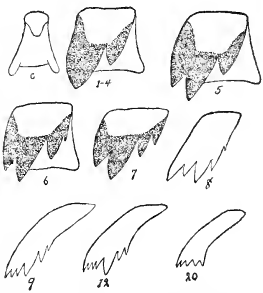


FIG. 7. Radula of *Limnaea cubensis* Pfr. C, central tooth; 1-4, first lateral teeth; 5, 6, 7, transition teeth; 8, 9, 12, 20, marginal teeth.

Distribution: New England to California, Michigan and Dakota to Texas and Mexico; Cuba.

Geological Distribution: Pleistocene; Loess.

Habitat: Similar to and almost always associated with *caperata*.

Remarks: This species, long known as *umbilicata*, has been shown by Mr. Pilsbry to be a synonym of *cubensis* Pfr.*

* Vide Proc. Phil. Acad. **1891**: 321.

It has been confounded with the closely allied species *caperata*, but is always a wider, more globose shell, and the aperture is generally longer than the spire, while in *caperata* the spire is always longer than the aperture. In *caperata* the aperture is elongately ovate while in *cubensis* it is roundly ovate. The spires of the two species are also quite different. Like *caperata* the present species is universally distributed throughout the area, but is not quite as common. Fossil specimens have been found in the sand banks along the lake shore north of Graceland Avenue.

7. LIMNAEA PALUSTRIS Müller.*

Pl. I. f. 1, 2.

Limnaea palustris Müller, Zool. Dan. Prodr. 2934. 1776.
Limnaeus elodes Say, Journ. Phil. Acad. 2: 169. 1821.
Limnaea umbrosa Say, Amer. Conch. *pl. xxxi. f. 1.* 1832.
Limnaea nuttalliana Lea, Proc. Amer. Phil. Soc. 2: 33. 1841.
Limnaea plebeia Gould, Invert. of Mass. 1841.
Limnaea expansa Haldeman, Mon. 29. *pl. ix. f. 6–8.* 1842.
Limnaea fragilis, Haldeman (non Linné), Mon. 20. *pl. vi. f. 1.* 1842.
Limnaea haydeni Lea, Proc. Phil. Acad. 1858: 166.
Limnaea sumassi Baird, Proc. Zool. Soc. London. 68. 1863.
Limnaea michiganensis Bryant Walker, The Nautilus. 6: 33. *pl. i. f. 9, 10.* 1892. (Variety.)
Limnaeus sufflatus W. W. Calkins, mss. (An expanded form of Haldeman's *expansa*)
Limnaea intertexta Currier, mss., vide Walker, The Nautilus. 6: 33. 1892.

Shell: Varying from elongate to elongate-ovate, rather thin; color varying from pale brown to almost jet black; surface dull to shining, covered with numerous crowded growth lines crossed by several elevated spiral lines and by numerous very fine impressed spiral lines, which give the surface a malleated aspect; the whorls are sometimes encircled by coarse wrinkles, and frequently the epidermis is so arranged as to show longitudinal stripes of white and horn color, alternating; whorls 6, rounded, the last varying in its rotundity; spire sharp and pointed, varying from over half to two thirds the length of the entire shell; sutures well impressed; aper-

* It is a grave question whether or not it is wise to make varieties of the numerous forms of this species, as there appears to be no limit to its variation. One may place specimens of this species in a row, beginning with the smaller narrow forms and trace the variation, without a break, to the wide, swollen, typical form.

ture roundly-ovate, more or less expanded; peristome thin, acute, sometimes expanded, in old specimens thickened by a heavy deposit within; the peristome is white and there is a band of very dark brown which edges the callus deposit; columella oblique, reflected, with a large fold across the middle, and covered by a heavy, whitish, testaceous deposit which is more or less spreading; umbilicus closed by the spreading callus and reflected columella, but the region is indented and the umbilicus is sometimes narrowly open.

Length	27.50;	width	9.50;	aperture	length	12.00;	width	5.00	mill.	(9323.)
"	23.00;	"	9.00;	"	"	11.00;	"	5.00	"	(8114.)
"	24.00;	"	10.00;	"	"	11.50;	"	5 50	"	(9884.)
"	26.00;	"	13.00;	"	"	15.00;	"	8.00	"	(8375.)
"	30 00;	"	12.00;	"	"	14.00;	"	7.12	"	(8115.)
"	26.00;	"	12.00;	"	"	12.25;	"	7.00	"	(8115.)
"	20.00;	"	9.00;	"	"	9.00;	"	4.50	"	(9695.)
"	15.50;	"	7.00;	"	"	8.50;	"	3.50	"	(9695.)
"	26.50;	"	11.00;	"	"	11.00;	"	6.00	"	(9695.)

Animal: With a short, wide foot, rounded before and behind; tentacles short, triangular; color black, lighter below, the body spotted with white which shows through the shell. Heart situated as usual, pulsation regular, 80–81 per minute. Length of foot 8.00, width 3.00 mills.

Jaw: As usual.

Radula formula: $\frac{21}{4+} + \frac{4}{3} + \frac{9}{2} + \frac{1}{1} + \frac{9}{2} + \frac{4}{3} + \frac{21}{4+}$ (34—1—34): central tooth as usual; lateral teeth of the usual type, bicuspid; transition teeth at first like laterals but tricuspid, the central cusp the largest (11) but soon (13) the inner cusps become more equal and the outer cusp small; marginal teeth of the usual type (*f. 8*). In one membrane examined (*f. 9*) the first

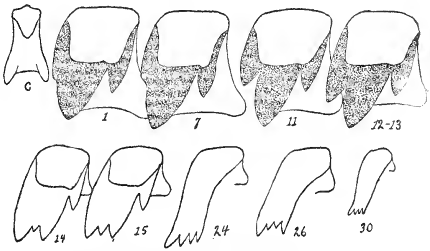


FIG. 8. Radula of *Limnaea palustris* Müller. C, central tooth; 1, first lateral; 7, seventh lateral; 11–13, intermediate teeth; 14–30, types of marginal teeth.

lateral to the right of the central tooth had a bifid outer cusp. This was observed in all the first laterals in this membrane.

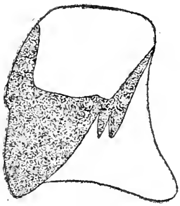


Fig. 9. First lateral of *L. palustris*, with bifid outer cusp.

Distribution: North America, Europe, Asia; circumpolar. Alaska (Randolph).

Geological Distribution: Pleistocene; Loess.

Habitat: Found in small streams and rivers, ponds and lakes, attached to floating sticks and submerged water plants.

Remarks: This is a very common and also a very variable species, as the list of synonyms which heads the description will attest. It is always a wide, more or less fusiform species, with the aperture and spire equal, or the latter a trifle longer, but never twice as long, as in *reflexa*. The malleation is usually, though not always, present. There seem to be no geographic races to this form, as all varieties may be found in a single small pool, as is the case near Bowmanville. The lip may be thin or thickened, without regard to size. Some forms are ornamented by numerous fine, incremental lines, much as in some land shells.

The food of the *Limnaeids* is supposed to be exclusively vegetable, but from some recent observations and from late notes of other naturalists it would seem that the group is carnivorous as well as scavengiferous. The writer has noted this species feeding upon dead carcasses (dogs, cats, etc.) and Dr. Sterki (The Nautilus. **5**: 94. 1891) has seen it in the act of eating a living leach. The species is found in almost all parts of the area and in some localities is the predominating form.

The animal of *palustris* is very rapid in movement. It crawls out of the water and will remain in this position for a long time. When crawling, the shell is frequently moved rapidly from side to side, and is carried at all conceivable angles. It is a very rapid feeder and will soon clear up the sides of an aquarium. Like other species of the genus, *palustris* has the habit of rising very suddenly from the bottom to the top of the water where it will then float shell downward.

7a. LIMNAEA PALUSTRIS MICHIGANENSIS Walker.

Pl. I. f. 5.

This form is characterized (although connected by intermediate forms with the type) by the aperture being about one half the total length, the outer lip is thickened within by a bluish-white callus edged with brownish black; this shows as a white longitudinal band on the outside of the shell. Mr. Walker mentions very fine spiral lines but these are as fully developed in the typical forms as in the variety.

Length	20.00;	width	8.00;	aperture length	9.00;	width	4.50 mill.	(12083.)
"	17.00;	"	7.00;	" "	8.50;	"	4.00 "	(12083.)
"	15.00;	"	7.00;	" "	8.00;	"	4.00 "	(12082.)

Habitat: Associated always with the type, but not as numerous in individuals.

8. LIMNAEA REFLEXA Say.

Pl. I. f. 3, 6.

Limneus reflexus Say, Journ. Phil. Acad. **2**: 167. 1821.

Limneus elongatus Say, l. c. 167. 1821.

Limnaea palustris var. *distortus*, Rossmässler, Icon. **1**: 97. *pl. ii. f. 52.* 1835.

Limnaea exilis Lea, Trans. Amer. Phil. Soc. **5**: 114. *pl. xix. f. 82.* 1837. (Variety.)

Limnaea kirthandiana Lea, Proc. Amer. Phil. Soc. **2**: 33. 1841. (Variety.)

Limnaea lanceata Gould, Proc. Bost. Soc. N. H. **3**: 64. 1848.

Limnaea zebra Tryon, Amer. Jour. Conch. **1**: 228. *pl. xxiii. f. 4.* 1865.

Shell: Very much elongated, narrow, thin, sometimes scalar; color honey-yellow to black, sometimes obscurely longitudinally banded; surface shining, covered with numerous closely crowded growth lines, sometimes showing very fine impressed spiral lines which reticulate the surface; the growth lines are also wavy and elevated, in some specimens forming elevated ridges of considerable size; apex smooth, brownish or blackish; whorls 6–7, elongate-rounded, last whorl dilated (compressed in some varieties), reflexed; spire very long and pointed, occupying about two-thirds of the entire length of the shell; sutures impressed; aperture lunate or elongate-ovate, narrowed at the upper part, very oblique in some specimens; peristome thin, sharp, thickened by a heavy callus on the inside, the callus chocolate or purplish in color; peristome whitish; lower part of peristome dilated;

columella oblique, with a heavy plait across its center, running up into the whorl and extending to the apex; the columella callus is heavy, wide and spreading, and, with the columella, is reflected so as to completely cover the umbilicus; umbilical region indented.

Length	20.00;	width	7.00;	aperture	length	7.50;	width	3.75	mill.	(8382.)
"	30.00;	"	9.00;	"	"	12.50;	"	5.50	"	(8384.)
"	36.50;	"	11.00;	"	"	14.00;	"	7.00	"	(8111.)
"	34.00;	"	10.00;	"	"	13.00;	"	6.00	"	(8111.)
"	30.50;	"	9.50;	"	"	12.50;	"	5.50	"	(8109.)
"	40.00;	"	13.00;	"	"	15.00;	"	8.50	"	(8109.)
"	38.00;	"	10.00;	"	"	13.50;	"	6.50	"	(8110.)
"	31.00;	"	9.50;	"	"	12.00;	"	7.00	"	(8110.)
"	37.00;	"	12.00;	"	"	16.00;	"	7.50	"	(8112.)

Animal: Bluish-black or black; foot short and wide, 12.50 mill. long, 6.50 mill. wide; other characters as in *palustris.* the head is carried but little in advance of the edge of the shell (*f. 10*).

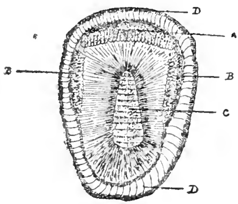


FIG. 10. Mouth parts of *Limnaea reflexa* Say. A, superior jaw; B, lateral jaws; C. radula; D. lips.

Jaws: As usual.

Radula formula: $\frac{24}{4+} + \frac{6}{3} + \frac{10}{2} + \frac{1}{1} + \frac{10}{2} + \frac{6}{3} + \frac{24}{4+}$ (40 — 1 — 40): central tooth as usual; lateral teeth with a subquadrate base of attachment; reflection large, a little longer than wide; bicuspid, the inner cusp very large and sub-bifid, the second part represented only by a swelling on the inner side of the cusp; the outer cusp is short and narrow, and pointed; intermediate laterals and marginals tricuspid, the central cusp long, the outer cusps short; as the marginals are approached the reflection becomes narrow and the inner cusp is placed nearer the top of the tooth; marginal teeth long and narrow, of the usual type (*f. 11*).

Distribution: Northern United States and Canada, from the Atlantic to the Pacific.

Geological Distribution: Pleistocene; Loess.

Habitat: Found plentifully in creeks, ponds, lakes and rivers, attached to pieces of floating wood, submerged vegetation, stones, etc. Also found attached to floating garbage, such as decaying apples, vegetables, etc.

Remarks: This is one of our most common species, and, excepting *L. stagnalis*, is the finest and largest *Limnaea* we have. It is always characterized by a long and attenuated spire which is twice as long as the aperture. In *palustris* the spire and aperture are nearly equal, and the shell is wider in proportion to its length than in *reflexa*, and the latter is very rarely malleated. There is great variation in the attenuation of the spire, some forms approaching var. *attenuata* in having a long, narrow, pointed spire (*Pl. 1. f. 3*). The figures well illustrate this variation.

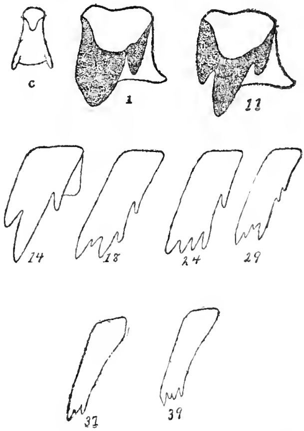


FIG. 11. Radula of *Limnaea reflexa* Say. C, central tooth; 1, first lateral; 11, 14, intermediate teeth; 18, 24, 29, 37, 39, eighteenth to thirty-ninth marginals.

The animal is generally rather sluggish in movement, but sometimes moves with considerable rapidity, especially when feeding. The species is as widely distributed in the present area as *palustris*.

Dr. Howard N. Lyon has raised this species from the egg and has presented the set showing age development to the Academy. Considerable variation is shown in the form of the shell, the young (12–16 weeks) looking very like *L. palustris*, the characteristic "twist" of *reflexa* not appearing until the 21st week. The measurements of the successive stages are as follows: —

6	weeks.	Length	2.00;	width	1.50	mill.
12	"	"	5.00;	"	2.75	"
12	"	"	10.00;	"	5.00	"
16	"	"	13.00;	"	6.00	"
16	"	"	20.50;	"	7.50	"
21	"	"	21.50;	"	9.00	"

(12-week entries:) This set shows that some individuals grow faster than others.

21 weeks.	Length 25.00;	width 9.00	mill.
33 "	" 26.50;	" 9.50	"
52 "	" 26.00;	" 11.50	"
52 "	" 28.50;	" 10.50	"

Another remarkable set showing development was presented by Dr. Lyon. The tablet contains fifteen specimens which were all killed when seventeen weeks old, yet the smallest is 4 mill. long and the largest 27 mill. All were fed on lettuce and contained in a four quart battery jar, under equal conditions of heat and light, and the brood was from a single egg capsule.

8a. LIMNAEA REFLEXA ATTENUATA Say.

Pl. I. f. 4.

Limnaea attenuata Say, New Harm. Diss. 2: 244. 1829.

Limnaea subulata Dunker, Küster, Chemn. ed. 2. p. 24. *pl. iv. f. 24.*

Shell: With an attenuated spire, which is more pointed than in *reflexa;* whorls 7, somewhat loosely coiled, leaving a well-marked suture, very convex; apex small, rounded, prominent; aperture about a third the length of the entire shell, lunate, thickened on the inside by a heavy callus; peristome thin; columella covered by a heavy callus and with a prominent plait; color light horn, sometimes darker, aperture dark horn, the callus yellowish, bordered with dark brown; other characters as in *reflexa.*

Length 24.00;	width 8.00;	aperture	length 9.50;	width 5.25 mill.
" 23.00;	" 7.75;	"	" 9.00;	" 5.00 "
" 22.00;	" 7.00;	"	" 8.75;	" 4.75 "

Animal, Jaw and *Dentition* as in *reflexa.*

Distribution: Same as *reflexa,* with the addition of Mexico.

Habitat: Same as *reflexa.*

Remarks: The present form cannot stand, in the writer's opinion, as a species. It intergrades with forms of *reflexa,* and cannot be satisfactorily separated from that species. It may, however, stand as a variety, characterized by an attenuated spire, rounded whorls and general scalariform shell. The variety is very rare and is only known from the vicinity of Joliet.

8b. LIMNAEA REFLEXA SCALARIS Walker.

Pl. I. f. 7.

Limnaea reflexa var. *scalaris* Bryant Walker, The Nautilus. **6**: 33. *pl. i. f. 7.* 1892.

This form is intermediate between the typical *reflexa* and its variety *attenuata*. It is in reality a scalariform condition, the whorls being well rounded and divided by a deep suture. The variety does not seem to be very common and is always found, at least in this area, associated with the type. It may be collected sparingly in Lake Calumet and near Joliet.

9. LIMNAEA STAGNALIS Linné.*

Plate I. f. 15.

Helix stagnalis Linné, Faun. Suecica. 2188. 1761.

Limnaea jugularis Say, Nich. Encycl. Amer. ed. 1816. (Variety.)

Limnaea appressa Say, Journ. Phil. Acad. **2**: 168. 1821.

Limnaea speciosa Ziegler, of Rossmässler, Icon. Land & Süssw. Moll. **1**: 96. *pl. 11. f. 50.* 1835.

Limnaea occidentalis Hemphill, The Nautilus. **4**: 26. 1890. (Variety.)

Limnaea sanctaemariae Walker, The Nautilus. **6**: 31. *pl. I. f. 4, 5.* 1892. (Variety.)

Shell: Elongated (or oval), ventricose at the anterior end, thin; color yellowish-horn to brownish-black; surface shining, growth lines numerous, crowded, more or less elevated, crossed by numerous fine, impressed spiral lines; apex smooth, brownish horn color; whorls 6½, rapidly increasing, all but the last two rather flat sided; last whorl very large, considerably dilated and inflated; spire long, pointed, acute, occupying about half the length of the entire shell (sometimes very short); sutures distinct but not very much impressed; aperture large, broadly ovate, dilated, particularly at the upper part; peristome thin, acute, in some specimens thickened by an internal callus; lower part rounded; colum

* It seems hardly necessary, or worth the time expended, to name the numerous varieties of this species recognized by European writers, and yet it may be of some interest to tabulate the names of some of these varieties as recorded in the Annales de la Société Malacologique de Belgique, 1872. **7**: 81, et seq. These are: *sinistrosa*, Jeff. (reversed), *lutea*, *maxima*, *expansa*, *quadrangulata*, *alba*, *erosa*, *regularis*, *distorta*, *aperta*, *biplicata*, *costulata*, all of Collin; *minima*, *gibbosa*, *illaqueata*, *scalaris*, *aquarii*, *arenaria*, *producta*, all of J. Colb.; *rosea*, Gass., *subfusca*, *major*, *pumila*, *turgida*, all of Moq. Tan.; *reseo-labiata* Wolf (Moq.), *fragilis* L. (Moq.). This list simply shows to what extent the system of varietal naming may be carried.

ella crossed in the middle by a very heavy plait, which starts from the base of the aperture and runs obliquely into the aperture of the shell about 10 mill. from the junction of the peristome with the body whorl; there is a spreading callus on the columella and labrum which completely covers the umbilicus.

Length	48.00;	width	21.50;	aperture length		26.00;	width	14.00	mill.	(8113.)
"	51.00;	"	22.50;	"	"	26.50;	"	15.00	"	(8113.)
"	33.00;	"	16.75;	"	"	18.50;	"	9.50	"	(8113.)
"	50.00;	"	20.00;	"	"	26.00;	"	12.00	"	(8113.)
"	62.00;	"	50.00;	"	"	33.00;	"	17.00	"	(Jensen.)
"	57.00;	"	24.00;	"	"	31.00;	"	14.50	"	(12315.)

Animal: Dark horn colored, tinged with bluish on the foot; head distinct, separated from the body by a constriction or neck, and produced into lateral flaps or vela; tentacles triangular, rather long, flat, the eyes placed on their bases; foot short and wide, truncated before and roundly pointed behind, 20.00 mill. long and 9.00 mill. wide; respiratory orifice very large, placed near the junction of the peristome with the body whorl. Heart situated midway between upper and lower ends of columella, pulsations varying from 37 to 48 per minute.

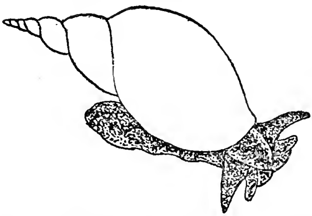


FIG. 12. Animal of *Limnaea stagnalis* Linné. (Canadian Naturalist. 2: 196.)

Jaw: As usual.

Radula formula: $\frac{2}{4+} + \frac{4}{2-3} + \frac{13}{2} + \frac{1}{1} + \frac{13}{2} + \frac{4}{2-3} + \frac{29}{4+}$ (46—1—46): central tooth as usual, a single membrane examined had the central tooth abnormal in possessing a denticle on the left side of the reflection (*f. 13, c.*); lateral teeth with a quadrate base of attachment, the reflection very large, reaching far below the base of attachment, bicuspid, the inner cusp very large, the outer cusp very small (the first lateral has a bifid inner cusp); intermediate teeth very long and narrow, bi- or tricuspid; marginal teeth very long and narrow, four- or more cuspid, the cusps being very blunt and small and extending irregularly along the outer edge of the teeth. The number of teeth seems to vary in different individuals; the writer has counted from 46—1—46 to 54—1—54; Binney (L. & F.W. Sh., p. 28) gives 40—1—40 and (p. 155) 47—1—47 teeth; Bland and Binney (Am. Journ. Conch. **7**: 161) give 40—1—40. It is probable that the membrane having 54—1—54 teeth was abnormal. 46—1—46 is the number generally counted by the writer (*f. 13*).

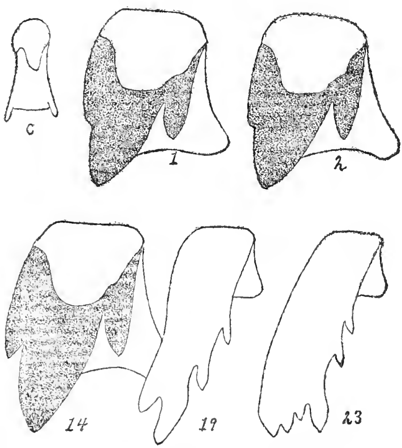


FIG. 13. Radula of *Limnaea stagnalis* Linné. C, central tooth, abnormal; 1, first lateral; 2, second lateral; 14, fourteenth lateral or first intermediate; 19, 23, marginal teeth.

Distribution: North America, Europe, Asia; circumpolar.

Geological Distribution: Pleistocene; Loess.

Habitat: Found generally in stagnant spots of ponds and rivers about decaying vegetation. Rotting fruit or vegetables floating in the water will be found a good habitat for this species. Dredged from a depth of ten meters at High Island Harbor, Lake Michigan (vide Bryant Walker).

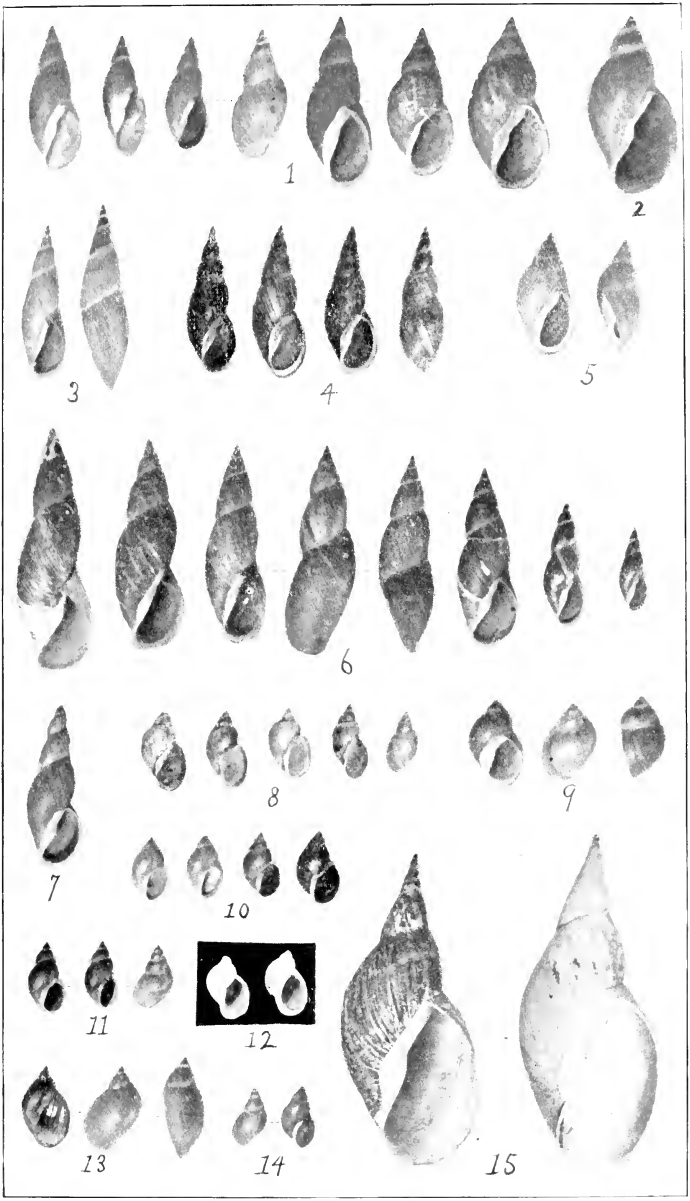
Remarks: This is our largest and finest *Limnaea*, easily distinguished by its large size, pointed spire and ample aperture. It varies to a great extent, principally in the form and size of the aperture, which is normally about the same length as the spire, but may be twice its length; it may also be elongately rounded or spreading and flaring. With all its variation, however, it is easily identified and cannot be mistaken for any other shell. This species may be classed with *palustris*, under the remarks on the latter species, in regard to its food. It has been seen about dead carcasses of a number of animals.

EXPLANATION OF ILLUSTRATIONS.

PLATE I.

1, *Limnaea palustris* Müller. — 2, *L. palustris* (*sufflatus* Calkins).—3, *L. reflexa* Say, elongate form. — 4, *L. reflexa* variety *attenuata* Say. — 5, *L. palustris* Müller variety *michiganensis* Walker. — 6, *L. reflexa* Say. — 7, *L. reflexa* variety *scalaris* Walker. — 8, *L. desidiosa* Say. — 9, *L. catascopium* Say. — 10, *L. cubensis* Pfeiffer. — 11, *L. caperata* Say. — 12, *L. catascopium* variety *pinguis* Say. — 13, *L. columella* Say. — 14, *L. humilis* Say. — 15, *L. stagnalis* Linné.

Issued January 16, 1901.



LIMNAEAS OF NORTHERN ILLINOIS.

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Transactions of The Academy of Science of St. Louis.

VOL. XI. No. 2.

FLORIDA LICHENS.

P. H. ROLFS.

Issued March 16, 1901.

FLORIDA LICHENS.*

P. H. Rolfs.

The lichens of the following list are in the herbarium of the Florida State Agricultural College at Lake City. The specimens were collected and determined during the writer's connection with that institution.

About eighty per cent. of the species were collected by Mr. Lovik T. Pattillo, a student in the college, who deserves unusual credit for his keen discrimination as an amateur collector and his untiring patience. The remainder of the specimens were collected by Mr. A. L. Quaintance, by the Sophomore classes, and by the writer.

The material, as collected, was shipped in what might be termed a rough condition to Mr. W. W. Calkins, of Chicago, well known among botanists for his work on lichens. The material was collected, labelled as to date, habitat, and locality and transferred to Mr. Calkins. The task of examining critically about 500 packages, each containing from one to an indefinite number of species, would seem enough to drown the enthusiasm of the most ardent.

The "Lichen-Flora of Florida," † published in 1887, enumerates 330 species and varieties. This list gives 48 species and varieties not mentioned in that paper, making 378 species and varieties catalogued for Florida, and the field is only partially explored.

Lichenologists interested in the species here enumerated will have no difficulty in securing access to the collection for study, if they desire.

The notes, common, abundant, rare, etc., have been furnished by Mr. Calkins and explain themselves.

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* Presented and read by title before The Academy of Science of St. Louis, February 18, 1901.

† Eckfeldt and Calkins, Jour. Mycol. **3**: 121–126, 133–137. 1887.

A rather full annotation of the habitats is given with a view of stimulating amateur collecting and thus securing larger representation of the Lichen flora. For this reason the common name, if specific enough, has been given preference.*

SERIES GYMNOCARPI.

TRIBE PARMELIACEI.

FAMILY USNEEI.

RAMALINA.

1. RAMALINA RIGIDA, (Pers.) Nyl.
   Common on dead oak.
2. RAMALINA RIGIDA, var. MONTAGNAEI, Tuck.
   On water oak.

USNEA.

3. USNEA BARBATA, (L.) Fr.
   On palmetto; cypress; persimmon.
4. USNEA BARBATA, var. FLORIDA, Fr.
   On dead cypress; water oak; scrub oak.
5. USNEA BARBATA, var. HIRTA, Fr.

FAMILY PARMELIEI.

PARMELIA.

6. PARMELIA CETRATA, Ach.
   Common on pine stump; dead cedar; cypress.
7. PARMELIA CRINITA, Ach.
   Common on dead oak.

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* The following annotations may be of service: Gum, *Nyssa;* pine stump, *P. palustris;* persimmon, *Diospyros;* pear, *Pyrus communis;* mulberry, *Morus rubra;* hickory, *Carya;* pine, *Pinus;* chinquapin oak, *Q. prinoides;* oak, *Quercus;* plum, *Prunus* (cultivated); linden *Tilia* sp.; thorny locust, *Gleditschia triacanthos;* wild cherry, *Prunus serotina;* live-oak, *Q. virens;* magnolia, *M. grandiflora;* palmetto, *Sabal, Serenoa;* cypress, *Taxodium;* willow oak, *Q. Phellos;* scrub oak, *Q.* sp.; saw palmetto, *Serenoa serrulata;* black oak, *Q. tinctoria?;* crape myrtle, *Lagerstroemia Indica;* red oak, *Q. rubra?;* blue gum, *Nyssa aquatica;* red cedar, *Juniperus Virginiana.*

8. Parmelia latissima, Fée.
On pine roof; dead oak; hickory; saw palmetto; wild cherry; *Xanthoxylum;* dead pine; *Crataegus.*
9. Parmelia perforata, (Jacq.) Ach.
Abundant. On pine stump; oak; hickory; persimmon.
10. Parmelia perlata, (L.) Ach.
On oak; palmetto; persimmon; orange; magnolia; pear; sassafras; black oak.
11. Parmelia perlata, var. ciliata, Ouctt.
On sassafras.
12. Parmelia physodes, (L.) Ach.
Rare. On hickory.
13. Parmelia tiliacea, (Hoffm.) Floerk.
Common. On dead cypress; hickory; crape myrtle; blue gum; oak.
14. Parmelia tiliacea, var. sublaevigata, Nyl.
On dead cypress; magnolia; hickory; *Bejaria;* sassafras; linden; plum; pear.

Physcia.

15. Physcia adglutinata, (Floerk) Nyl.
16. Physcia crispa, Nyl.
On oak; palmetto; magnolia; dead live-oak; hickory.
17. Physcia crispa, var. hypomela, Tuck.
On wild cherry.
18. Physcia stellaris, (L.) Nyl.
Common. On mulberry; red cedar; linden; hickory.

Pyxine.

19. Pyxine cocoes, (Sw.) Nyl.
On palmetto.
20. Pyxine meissneri, Tuck.
Very rare. On *Carpinus.*
21. Pyxine picta, (Sw.) Tuck.
Abundant. On scrub oak.
22. Pyxine sorediata, Fr.
On *Ficus; Sabal.*

Family Peltigerei.

Sticta.

23. Sticta aurata, (Sw.) Ach.
On magnolia.

24. Sticta quercizans, (Michx.) Ach.
On magnolia; *Crataegus;* red oak.

Family Pannariei.

Pannaria.

25. Pannaria molybdaea, (Pers.) Tuck.
Not common. On crape myrtle; red cedar; dead live-oak; water oak; *Carpinus;* scrub oak; magnolia; persimmon; *Andromeda.*

26. Pannaria rubiginosa, (Thunb.) Delis.
Abundant. On red oak; black oak; *Andromeda.*

27. Pannaria stellata, (Tuck.) Nyl.
Abundant. On *Carpinus.*

Family Collemei.

Collema.

28. Collema aggregatum, Nyl.
Abundant. On dead cypress; scrub oak.

29. Collema nigrescens, Fr.
Common. On hickory.

30. Collema nigrescens, var. leucopepla, Tuck.
On linden.

Leptogium.

31. Leptogium marginellum, (Sw.) Mont.
On red cedar; linden; *Carpinus;* oak; mulberry; *Liquidambar.*

32. Leptogium myochroum, (Ehrh.) Tuck.
On sassafras.

33. Leptogium myochroum, var. saturninum, Schaer.

34. Leptogium pulchellum, (Ach.) Nyl.
On *Cornus florida; Carpinus;* linden.

35. LEPTOGIUM TREMELLOIDES, (L. f.) Fr.
Abundant. On red cedar; magnolia; *Carpinus;* black oak; hickory.

FAMILY LECANOREI.

PLACODIUM.

36. PLACODIUM CERINUM, (Hedw.) Naeg. & Hepp.
On red oak; linden; chinquapin oak.

LECANORA.

37. LECANORA ATRA, (Huds.) Ach.
Very common. On mulberry; *Liquidambar;* persimmon; blue gum; linden; chinquapin oak; magnolia.

38. LECANORA CONIZAEA, Ach.
On pine.

39. LECANORA CUPRESSI, Tuck.
Very common. On dead pine; cypress.

40. LECANORA GRANIFERA, Ach.
On *Carpinus.*

41. LECANORA PALLIDA, (Schreb.) Schaer.
Abundant. On mulberry; red cedar; hickory; scrub oak; persimmon; live-oak.

42. LECANORA PALLIDA, var. CANCRIFORMIS, Tuck.
Abundant. On linden; water oak.

43. LECANORA PALLESCENS, (L.) Schaer.
On hickory; *Ilex.*

44. LECANORA PULCHELLA, Ach.
On blue gum; willow oak; oak; water oak.

45. LECANORA PUNICEA, Ach.
Very abundant. On water oak; chinquapin oak; live-oak; young oak; red oak; *Myrica;* wild cherry; mulberry; hickory; cypress; *Cornus florida; Xanthoxylum.*

46. LECANORA SUBFUSCA, (L.) Ach.
Common. On mulberry; cypress; *Cornus florida;* hickory; persimmon; water oak.

47. LECANORA VARIA, (Ehrh.) Nyl.
On *Castanea;* dead cypress; *Myrica;* wild cherry; linden; chinquapin oak; live oak.

48. Lecanora varia, var. symmicta, Ach.
On mulberry; hickory; scrub oak.

49. Lecanora xanthophana, Nyl.
Rare. On magnolia.

Rinodina.

50. Rinodina constans, (Nyl.) Tuck.
Rare. On magnolia.

51. Rinodina flavo-nigella, Tuck.
Rare. On rotten log; stump; dead live-oak; persimmon; black-jack oak.

Pertusaria.

52. Pertusaria communis, DC.
Common. On oak; red oak; black oak; persimmon; hickory.

53. Pertusaria leioplaca, Kbr.
Abundant. On mulberry; linden; magnolia; red oak; hickory; live-oak; *Liquidambar;* chinquapin oak.

54. Pertusaria multipuncta, (Turn.) Nyl.
On live-oak; hickory; oak stump; magnolia; pine; oak; water oak; pine stump; *Cornus florida;* linden; red oak; plum; *Ilex opaca;* dead pine.

55. Pertusaria pustulata, (Ach.), Nyl.
On *Myrica;* chinquapin oak.

56. Pertusaria velata, (Turn.) Nyl.
Common. On *Carpinus;* magnolia.

57. Pertusaria wulfenii, DC.
Rare. On hickory; *Carpinus.*

Gyalecta.

58. Gyalecta lutea, (Dicks.) Tuck.
On *Cornus florida.*

59. Gyalecta pineti, (Schrad.) Tuck.
On pine; *Polyporus.*

Thelotrema.

60. Thelotrema domingense, (Fée, Nyl.) Tuck.
Common. On *Ulmus;* hickory.

61. Thelotrema glaucescens, Nyl.
Rare. On hickory.
62. Thelotrema interpositum, (Nyl.) Tuck.
On oak; pine; *Gordonia*.
63. Thelotrema subtile, Tuck.
Abundant. On *Carpinus; Cornus florida*.

Gyrostomum.

64. Gyrostomum scyphuliferum, (Ach.) Fr.
Very common. On oak; persimmon; *Carpinus;* mulberry; pear; hickory; wild cherry; *Xanthoxylum; Myrica;* crape myrtle; chinquapin oak.

Myriangium.

65. Myriangium duriaei, (M. & B.) Tuck.
On thorny locust; blue gum.

TRIBE LECIDEACEI.

Family Cladoniei.

Cladonia.

66. Cladonia fimbriata, (L.) Fr.
Common. On saw palmetto; cabbage palmetto; pine log; pine stump; dead live-oak; magnolia; dead pine.
67. Cladonia gracilis, (L.) Nyl.
On pine log.
68. Cladonia gracilis, var. reticulata, Fr.
On sand.
69. Cladonia leporina, Fr.
On sand; old pine roof; pine stump; saw palmetto.
70. Cladonia macilenta, (Ehrh.) Hoffm.
On old pine stump.
71. Cladonia mitrula, Tuck.
On oak; dead live-oak; damp earth.
72. Cladonia pulchella, Schw.
On dead pine.
73. Cladonia rangiferina, var. alpestris, L.
On old pine roof; sand.

74. Cladonia rangiferina, var. sylvatica, L.
On saw palmetto; sand.
75. Cladonia squamosa, var. botryoides, Tuck.
On pine stumps.

Biatora.

76. Biatora atropurpurea, (Mass.) Hepp.
On willow oak.
77. Baitora carneo-albens, (Nyl.) Calkins.
78. Biatora exigua, (Chaub.) Fr.
On *Myrica*.
79. Biatora floridana, Calkins.
On *Carpinus*.
80. Biatora furfurosa, Tuck.
On magnolia.
81. Biatora fusco-rubella, Hoffm.
On *Cornus florida;* water oak.
82. Biatora hypomela, Nyl.
On water oak; magnolia.
83. Biatora parvifolia, (Pers.) Tuck.
On magnolia; sassafras; *Carpinus*.
84. Biatora parvifolia, var. corallina, Tuck.
85. Biatora parvifolia, var. granulosa, Tuck.
On magnolia.
86. Biatora parvifolia, var. subgranulosa, Tuck.
On magnolia.
87. Biatora rubella, (Ehrh.) Rab.
On dead cypress; linden; magnolia; mulberry; hickory; *Liquidambar*.
88. Biatora schweinitzii, Fr.
On sassafras; *Cornus florida;* hickory: *Liquidambar;* water oak.
89. Biatora tricholoma, Mont.
Rare. On live-oak.
90. Biatora varians, (Ach.) Tuck.
On persimmon; wild cherry; chinquapin oak.
91. Biatora vernalis, (L.) Fr.
On palmetto.

Heterothecium.

92. Heterothecium domingense, (Pers.) Flot.
On magnolia; *Carpinus;* hickory; *Liquidambar;* water oak.
93. Heterothecium leucoxanthum, (Spreng.) Mass.
Common. On hickory; magnolia; *Cornus florida;* oak; black oak; *Ilex opaca;* linden; mulberry; willow oak; *Liquidambar.*
94. Heterothecium tuberculosum, (Fée) Flot.
On magnolia.
95. Heterothecium vulpinum, Tuck.
Abundant on magnolia.

Lecidea.

96. Lecidea disciformis, Nyl.
On plum; magnolia; wild cherry; blue gum; live-oak; chinquapin oak.

Buellia.

97. Buellia myriocarpa, (DC.) Mudd.
Common. On *Myrica.*
98. Buellia parasema, (Ach.) Th. Fr.
Common. On dead pines; on dead cypress; mulberry; cypress; magnolia; *Myrica;* hickory; scrub oak; *Bejaria.*

TRIBE GRAPHIDIACEI.

Family Lecanactidei.

Platygrapha.

99. Platygrapha ocellata, Nyl.
Very rare. On *Carpinus.*

Family Opegraphei.

Opegrapha.

100. Opegrapha astraea, Tuck.
On linden.

101. Opegrapha bonplandi, Fée.
Common. On oak.

102. Opegrapha similis, Pers.
On hickory.

103. Opegrapha varia, (Pers.) Fr.
Common. On *Carpinus;* mulberry; magnolia; *Cornus florida.*

104. Opegrapha viridis, Pers.
On hickory.

105. Opegrapha vulgata, Ach.
Common. On water oak.

Graphis.

106. Graphis abaphoides, Nyl.
Not common. On *Persea.*

107. Graphis adscribens, Nyl.
Tropical. On mulberry; *Persea; Gordonia;* hickory.

108. Graphis afzelii, Ach.
Very abundant. On *Carpinus;* hickory; *Myrica;* water oak; scrub oak; pear; *Ilex opaca;* blue gum; live-oak.

109. Graphis assimilis, Nyl.
Not rare. On mulberry.

110. Graphis comma, Ach.
On oak; hickory.

111. Graphis dendritica, Ach.
Common. On *Xanthoxylum;* deak oaks; plum; wild cherry; chinquapin oak; pear; live oak.

112. Graphis elegans, (Sw.) Ach.
Not common. On *Carpinus;* linden; hickory; magnolia; persimmon

113. Graphis elegans, var. striatula, Ach.
Rare. On oak; magnolia; linden.

114. Graphis erumpens, Nyl.
Common. On *Xanthoxylum; Nyssa.*

115. Graphis glaucoderma, Nyl.
On magnolia; *Carpinus;* mulberry.

116. Graphis inusta, Ach.
On hickory.

117. GRAPHIS NITIDA, (Eschw.) Nyl.
Rare. On *Myrica.*

118. GRAPHIS NITIDESCENS, Nyl.
Very rare. On *Carpinus;* linden.

119. GRAPHIS PATELLULA, (Meiss.) Nyl.
On hickory; scrub oak.

120. GRAPHIS POITAEOIDES, Nyl.
Not common. On crape myrtle.

121. GRAPHIS SCALPTURATA, Ach.
On *Myrica;* hickory; red oak; linden.

122. GRAPHIS SCRIPTA, (L.) Ach.
Common. On wild cherry; red oak; plum; hickory; pear; *Myrica;* crape myrtle; blue gum; willow oak; magnolia; water oak.

123. GRAPHIS SCRIPTA, var. RECTA, Schaer.
On wild cherry.

124. GRAPHIS SCRIPTA, var. SERPENTINA, Sch.
On mulberry; hickory; linden.

125. GRAPHIS SOPHISTICA, Nyl.
Not rare. On pear; willow oak; live oak; chinquapin oak.

126. GRAPHIS SUBPARALIS, Nyl.
On magnolia.

127. GRAPHIS SUBSTRIATULA, Nyl.
On water oak.

128. GRAPHIS SUBVIRGINALIS, Nyl.
On hickory; oak.

129. GRAPHIS TENELLA, Ach.
Common. On hickory; *Myrica;* oak; mulberry; pear; blue gum; water oak; *Carpinus;* chinquapin oak; plum; *Xanthoxylum; Liquidambar.*

130. GRAPHIS TRICOSA, Ach.
Rare. On *Myrica;* mulberry; pear; wild cherry; crape myrtle; chinquapin oak; linden.

ENTEROGRAPHA.

131. ENTEROGRAPHA ELEGANS, Eschw.
Very rare. On black oak.

STIGMATIDIUM.

132. STIGMATIDIUM INSCRIPTUM, Nyl.
Abundant. On *Carpinus.*

FAMILY GLYPHIDEI.

CHIODECTON.

133. CHIODECTON MONTAGNAEI, Tuck.
Common. On hickory; oak stump; magnolia; red oak; *Carpinus;* oak; *Ilex opaca;* mulberry; *Liquidambar;* dead pine; willow oak; linden; pine.
134. CHIODECTON RUBRO-CINCTUM, Nyl.
Very common. On palmetto; magnolia; dead cedar; dead pine; *Crataegus.*

GLYPHIS.

135. GLYPHIS ACHARIANA, Tuck.
Common. On oak; *Xanthoxylum; Myrica;* pear; crape myrtle; hickory.
136. GLYPHIS CRIBOSA, Ach.
On hickory; linden.
137. GLYPHIS FAVULOSA, Ach.
On mulberry; willow oak; linden; water oak.

FAMILY ARTHONIEI.

ARTHONIA.

138. ARTHONIA ASTEROIDEA, Ach.
Not common. On chinquapin oak.
139. ARTHONIA CINNABARRINA, Wallr.
Common. On wild cherry; cabbage palmetto scabbard; *Xanthoxylum; Ilex opaca; Cornus florida;* linden; hickory; live oak; chinquapin oak.
140. ARTHONIA DISPERSA, Nyl.
On persimmon; pear; *Hamamelis;* oak; *Myrica.*
141. ARTHONIA FLORIDANA, Willey.
Rare. On *Myrica; Ilex opaca.*
142. ARTHONIA INTERVENIENS, Nyl.
On thorny locust.

143. Arthonia punctiformis, Ach.
On *Cornus florida;* linden.

144. Arthonia pyrrhula, Nyl.
On mulberry; *Myrica.*

145. Arthonia pyrrhuliza, Nyl.
On mulberry; *Myrica;* chinquapin oak.

146. Arthonia quintaria, Nyl.
Abundant. On wild cherry; *Myrica.*

147. Arthonia rubella, Fée.
Common. On linden.

148. Arthonia spectabilis, Flot.
On mulberry; hickory; *Myrica;* pine.

149. Arthonia taediosa, Nyl.
Not common. On *Myrica;* oak; plum; *Pinus clausa;* chinquapin oak; pear; *Xanthoxylum;* linden.

Mycoporum.

150. Mycoporum pycnocarpum, Nyl.
Common. On persimmon; *Pinus clausa; Xanthoxylum.*

TRIBE CALICIACEI.

Family Caliciei.

Acolium.

151. Acolium carolinianum, Tuck.
On pine stump.

152. Acolium javanicum, (M. & Vd. B.) Stitz.
On gum.

SERIES ANGIOCARPI.

TRIBE VERRUCARIACEI.

Family Verrucariei.

Segestria.

153. Segestria nucula, (Fr.) Ach.
On hickory; linden; magnolia; oak; mulberry; *Liquidambar; Cornus florida;* willow oak.

Trypthelium.

154. Trypthelium (Pyrenula) aggregata, Fée.
Common. On *Myrica.*
155. Trypthelium catervarium, (Fée) Tuck.
Rare. On *Myrica.*
156. Trypthelium mastoideum, Ach.
On mulberry; pear; *Myrica;* linden; hickory; red oak; *Xanthoxylum.*
157. Trypthelium achroleum, Nyl.
On hickory; pear.
158. Trypthelium achroleum, var. pallescens, Müller.
On mulberry; hickory.
159. Trypthelium cruentum, Mont.
On mulberry; blue gum; pear; plum.
160. Trypthelium pyrenuloides, Mont.
Abundant. On linden; *Carpinus;* hickory; water oak; willow oak; *Cornus florida;* magnolia; mulberry.
161. Trypthelium scorites, (Tuck.) Nyl.
Abundant. On oak; *Ilex opaca;* willow oak; hickory.
162. Trypthelium virens, Tuck.
Abundant. On blue gum.

Pyrenula.

163. Pyrenula cinchonae, (Ach.) Tuck.
On *Myrica.*

164. Pyrenula fallax, Nyl.
Common. On *Xanthoxylum;* plum; blue gum.

165. Pyrenula gemmata, Ach.
On *Carpinus;* hickory.

166. Pyrenula glabrata, Ach.
On hickory; oak; pear; linden.

167. Pyrenula mamillana, Ach.
On *Carpinus;* linden; *Ilex opaca;* wild cherry; *Myrica;* magnolia.

168. Pyrenula nitida, Ach.
On oak stump; chinquapin oak; *Myrica;* willow oak; water oak; linden.

169. Pyrenula ochraceo-flava, Nyl.
On mulberry; live-oak.

170. Pyrenula punctiformis, Ach.
On *Xanthoxylum; Pinus clausa;* hickory.

171. Pyrenula quinque-septata, (Nyl.) Tuck.
On *Myrica.*

172. Pyrenula subprostans, (Nyl.) Tuck.
Common. On oak.

173. Pyrenula tropica, (Ach.) Tuck.
Rare. On mulberry; hickory; pear.

Pyrenastrum.

174. Pyrenastrum astroideum, (Fée) Eschw.
On magnolia; *Ilex opaca;* hickory; wild cherry.

175. Pyrenastrum ravenelii, Tuck.
On linden.

Strigula.

176. Strigula complanata, (Fée & Mont.) Nyl.
On magnolia leaves.

Issued March 16, 1901.

PUBLICATIONS.

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Transactions of The Academy of Science of St. Louis.

VOL. XI. No. 3.

ISOGONIC TRANSFORMATION.

T. G. POATS.

Issued May 16, 1901.

ISOGONIC TRANSFORMATION.*

T. G. Poats.

In this paper the expression Isogonic Transformation is used to indicate the transformation of a figure which results from the projection of its points along circular arcs which measure equal angles at the feet of the ordinates of the respective points. For instance, if the ordinate drawn to P' (Fig. 1)

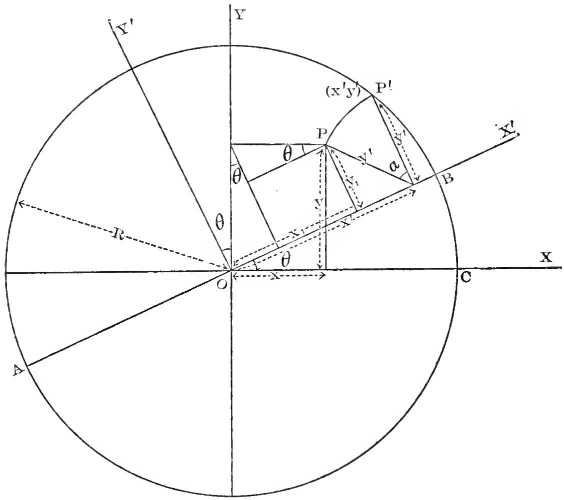

Fig. 1.

is turned through an angle a about its foot and, likewise, the ordinates from all the other points of the circumference are turned each through the same angle a, the resulting figure is the isogonic transformation of the circle.

* Presented in abstract to The Academy of Science of St. Louis, Jan. 21, 1901.

Referring to Fig. 1, let the circle $P'BCA$ be given by its equation

$$x'^2 + y'^2 = R^2$$

referred to the rectangular axes OX', OY'.

Take any point P' in the circumference whose co-ordinates are x', y' and turn the ordinate y' through an angle a bringing P' to P.

The co-ordinates of P referred to OX', OY' are x_1, y_1.

Treat every point of the circumference in the same way and we shall have (Fig. 2) the circle transformed into an ellipse.

Proof:

$$x'^2 + y'^2 = R^2 \qquad (1)$$

is the equation to the circle referred to OX', OY'.

The co-ordinates of P' in terms of those of P are

$$x' = x_1 + y_1 \tan a$$
$$y' = y_1 \sec a,$$

and the new locus has for its equation

$$(x_1 + y_1 \tan a)^2 + (y_1 \sec a)^2 = R^2$$

or

$$x_1^2 + y_1^2 + 2y_1^2 \tan^2 a + 2x_1y_1 \tan a = R^2. \qquad (2)$$

which is the equation of an ellipse.

Now let us refer the conic to the axes OX, OY, which make an angle θ with OX', OY' respectively, and let the new co-ordinates of P referred to OX, OY be x, y.

For changing from the axes OX', OY' to the axes OX, OY

$$x_1 = y \sin \theta + x \cos \theta$$
$$y_1 = y \cos \theta - x \sin \theta.$$

Substituting and separating terms equation (2) becomes

$$x^2 \left| \begin{array}{l} +1 \\ -\tan a \sin 2\theta \\ +2\tan^2 a \sin^2 \theta \end{array} \right. + y^2 \left| \begin{array}{l} +1 \\ +\tan a \sin 2\theta \\ +2\tan^2 a \cos^2 \theta \end{array} \right.$$

$$+ 2xy \left| \begin{array}{l} \tan a \cos 2\theta \\ -\tan^2 a \sin 2\theta \end{array} \right. = R^2. \qquad (3)$$

Making the coefficient of xy zero to get rid of the term involving xy, we have

$$\tan a \cos 2\theta - \tan^2 a \sin 2\theta = 0$$

$$\cot 2\theta = \tan a$$

Hence

$$2\theta = 90^\circ - a$$

$$\theta = 45^\circ - \frac{a}{2}.$$

For this value of θ equation (3) becomes of the general form

$$Ax^2 + By^2 = R^2,$$

in which

$$A = \frac{1}{1 + \sin a},$$

and

$$B = \frac{1}{1 - \sin a}.$$

Equation (3) now becomes

$$\frac{x^2}{R^2 (1 + \sin a)} + \frac{y^2}{R^2 (1 - \sin a)} = 1 \qquad (4)$$

which is the equation to the ellipse whose constants are: —

semi-major axis, $a = R \sqrt{1 + \sin a}$,

semi-minor axis, $b = R \sqrt{1 - \sin a}$,

eccentricity, $e = \sqrt{\frac{a^2 - b^2}{a^2}}$

$$= \sqrt{\frac{R^2 (1 + \sin a) - R^2 (1 - \sin a)}{R^2 (1 + \sin a)}}$$

$$= \sqrt{\frac{2 \sin a}{1 + \sin a}},$$

focal distance, $c = ae$

$$= R \sqrt{1 + \sin a} \sqrt{\frac{2 \sin a}{1 + \sin a}}$$

$$= R \sqrt{2 \sin a}.$$

When $a = 30°$, $c = R$, and the focus is on the circumference of the circle.

(This ellipse is the common isometric projection of the circle.)

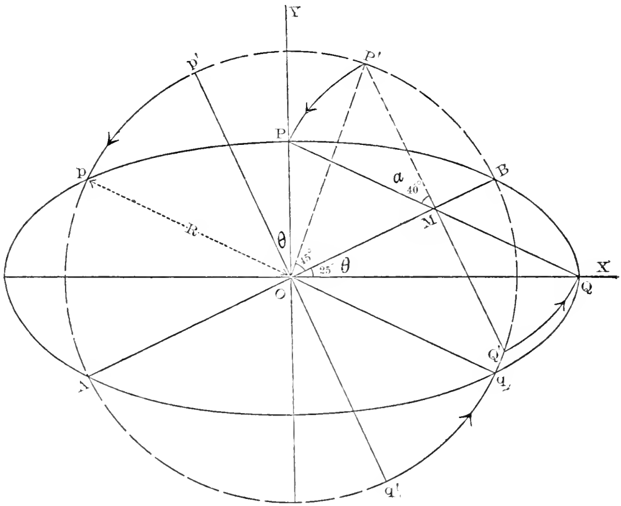

Fig. 2.

To determine common points of ellipse and circle we have

$$\left.\begin{array}{l} x^2 + y^2 = R^2 \\ \dfrac{x^2}{1 + \sin a} + \dfrac{y^2}{1 - \sin a} = R^2 \end{array}\right\} \text{referred to } OX,\ OY,$$

whence

$$x = \pm R \cos \theta$$

and

$$y = \pm R \sin \theta.$$

These two equations give us the points A, B, p, q, (Fig. 2).

To determine the vertices of the ellipse we have (Fig. 2)

$$\tan \angle PQO = \frac{PO}{OQ} = \frac{b}{a} = \frac{R\sqrt{1-\sin a}}{R\sqrt{1+\sin a}}$$

$$= \sqrt{\frac{1 - \dfrac{1-\tan^2\theta}{1+\tan^2\theta}}{1 + \dfrac{1-\tan^2\theta}{1+\tan^2\theta}}}$$

$$= \tan\theta.$$

Hence

$$\angle PQO = \theta$$

and

$$\angle POM = \angle OPM = 90^\circ - \theta$$
$$OM = MP = MQ = P'M;$$

therefore

$$\angle P'OB = 45^\circ$$

The vertices may consequently be determined at once as well as the position and length of the axes.

To rectify this ellipse

$$L = 2\pi a\left(1 - \frac{e^2}{2^2} - \frac{3\,e^4}{2^2 . 4^2} - \frac{3^2 . 5\,e^6}{2^2 . 4^2 . 6^2} - \ldots .\right)$$

in which

$$e^2 = \frac{2\sin a}{1+\sin a}$$

and

$$a = R\sqrt{1+\sin a};$$

hence

$$L = 2\pi R\sqrt{1+\sin a}\left(1 - \frac{1}{2}\cdot\frac{\sin a}{(1+\sin a)} - \frac{3}{16}\cdot\frac{\sin^2 a}{(1+\sin a)^2} - \frac{5}{32}\cdot\frac{\sin^3 a}{(1+\sin a)^3} - \ldots .\right)$$

When

$a = 0^\circ$	$L = 2\pi R$	Circle	Maximum perimeter.
$a = 90^\circ$	$L = 4\,R\sqrt{2}$	Straight line	Minimum perimeter.

Area of the ellipse

$$A = \pi ab = \pi \cdot R\sqrt{1+\sin a} \cdot R\sqrt{1-\sin a}$$
$$= \pi R^2 \cos a$$

The area of this ellipse varies therefore as cos a. We have then special cases as follows: —

$a = 0°$	$A = \pi R^2$	Circle	Maximum area.
$a = 90°$	$A = 0$	Straight Line	Minimum area.

It will be seen from the above equation for the area and from the transformed areas of other figures that the area of the transformed figure is obtained by multiplying the original area by cos a.

It will also be observed that the area of the transformed figure is the same as that of the orthographic projection of the original figure on a plane at angle a with the plane of the original figure.

Isogonic Transformation may be applied equally well to solids.

Let us take its application to a sphere (Fig. 3) referred to the rectangular axes OX', OY', OZ', whose equation is

$$x'^2 + y'^2 + z'^2 = R^2. \qquad (5)$$

Let P' be any point on the sphere and let the co-ordinates of P' be x', y', z'.

Turn the ordinate z' through an angle a about its foot, keeping it always parallel with the $X'Z'$ plane. P' will go to P whose co-ordinates are x_1, y_1, z_1.

Now, turning the co-ordinate system backward through an angle θ (to be determined later) about OY' we have xyz as the new co-ordinates of P referred to OX, OY, OZ.

The equations for the first transformation are

$$x' = x_1 + z_1 \tan a$$
$$y' = y_1$$
$$z' = z_1 \sec a$$

and equation (5) becomes

$$(x_1 + z_1 \tan a)^2 + y_1^2 + (z_1 \sec a)^2 = R^2$$

or

$$x_1^2 + 2x_1 z_1 \tan a + y_1^2 + z_1^2 + 2z_1^2 \tan^2 a = R^2 \qquad (6)$$

The equations for the second transformation are

$$x_1 = z \sin\theta + x\cos\theta$$
$$y_1 = y$$
$$z_1 = z\cos\theta - x\sin\theta$$

and equation (6) becomes, after assembling terms,

$$x^2\left|\begin{array}{l} +\cos^2\theta \\ -2\tan\alpha\sin\theta\cos\theta \\ +\sin^2\theta \\ +2\tan^2\alpha\sin^2\theta \end{array}\right. + y^2 + z^2\left|\begin{array}{l} +\sin^2\theta \\ +2\tan\alpha\sin\theta\cos\theta \\ +\cos^2\theta \\ +2\tan^2\alpha\cos^2\theta \end{array}\right.$$

$$+\,2xz\left|\begin{array}{l} +\sin\theta\cos\theta \\ +\tan\alpha\cos^2\theta \\ -\tan\alpha\sin^2\theta \\ -\sin\theta\cos\theta \\ -2\tan^2\alpha\sin\theta\cos\theta \end{array}\right. = R^2. \qquad (7)$$

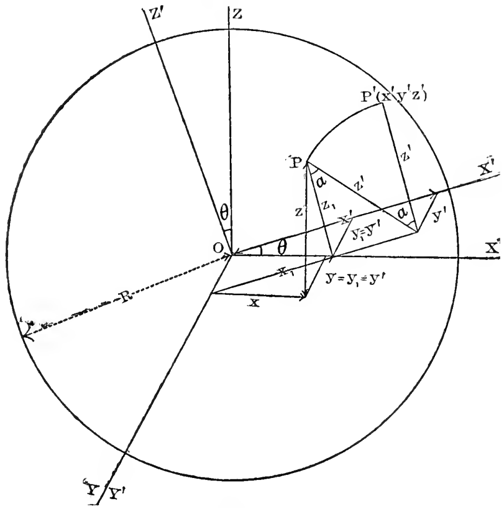

Fig. 3.

Making the coefficient of xz zero it is found that

$$\theta = \frac{1}{2}(90° - \alpha)$$

It will be seen from equation (7) that the coefficients of x^2 and z^2 are the same as the coefficients of x^2 and y^2 in the case of the circle.

Equation (7) is therefore of the general form

$$Ax^2 + By^2 + Cz^2 = R^2,$$

in which

$$A = \frac{1}{1 + \sin a}$$

$$B = 1$$

$$C = \frac{1}{1 - \sin a}$$

and may be written

$$\frac{x^2}{R^2(1 + \sin a)} + \frac{y^2}{R^2} + \frac{z^2}{R^2(1 - \sin a)} = 1, \qquad (8)$$

which is the equation to the ellipsoid, whose semi-axes are

$$a = R\sqrt{1 + \sin a}, \qquad b = R, \qquad c = R\sqrt{1 - \sin a}.$$

Its volume is

$$V = \frac{4}{3}\pi abc = \frac{4}{3}\pi R^3 \cos a$$

which is the volume of the sphere multiplied by $\cos a$.

Lastly, let us apply this method of transformation to the prolate spheroid, taking the longest axis as the y axis and the equal axes as the x and z axes.

Adapting its equation (Fig. 3), we have

$$\frac{x'^2 + z'^2}{a^2} + \frac{y'^2}{b^2} = 1$$

or

$$b^2(x'^2 + z'^2) + a^2 y'^2 = a^2 b^2. \qquad (9)$$

Transforming by means of the equations

$$x' = x_1 + z_1 \tan a$$

$$y' = y_1$$

$$z' = z_1 \sec a$$

we have

$$b^2x_1^2 + 2b^2x_1z_1 \tan a + b^2z_1^2 \tan^2 a \\ + b^2z_1^2 \sec^2 a + a^2y_1^2 = a^2b^2. \qquad (10)$$

Again transforming by means of

$$\begin{aligned} x_1 &= z \sin\theta + x\cos\theta \\ y_1 &= y \\ z_1 &= z\cos\theta - x\sin\theta \end{aligned}$$

equation (10) becomes

$$b^2x^2 \left| \begin{array}{l} + \cos^2\theta \\ - 2\tan a \sin\theta\cos\theta \\ + \sin^2\theta \\ + 2\tan^2 a \sin^2\theta \end{array} \right. + a^2y^2 + b^2z^2 \left| \begin{array}{l} + \sin^2\theta \\ + 2\tan a \sin\theta\cos\theta \\ + \cos^2\theta \\ + 2\tan^2 a \cos^2\theta \end{array} \right.$$

$$+ 2b^2 xz \left| \begin{array}{l} + \sin\theta\cos\theta \\ + \tan a \cos^2\theta \\ - \tan a \sin^2\theta \\ - \sin\theta\cos\theta \\ - 2\tan^2 a \sin\theta\cos\theta \end{array} \right. = a^2b^2. \qquad (11)$$

From the coefficient of xz in (11) it is seen that

$$2\theta = 90^\circ - a$$
$$\theta = 45^\circ - \frac{a}{2}$$

and

$$A = \frac{b^2}{1 + \sin a}$$
$$B = a^2$$
$$C = \frac{b^2}{1 - \sin a}.$$

Equation (11) now becomes

$$\frac{b^2x^2}{1 + \sin a} + a^2y^2 + \frac{b^2z^2}{1 - \sin a} = a^2b^2$$

or

$$\frac{x^2}{a^2(1 + \sin a)} + \frac{y^2}{b^2} + \frac{z^2}{a^2(1 - \sin a} = 1 \qquad (12)$$

which is the equation to the ellipsoid whose volume is

$$V = \frac{4}{3} \pi a^2 b \cos \alpha.$$

This is the volume of the prolate spheroid generator multiplied by cos α.

It may also be seen from equation (12) that the oblate spheroid is derived from the prolate spheroid when

$$a^2 (1 + \sin \alpha) = b^2$$

or

$$1 + \sin \alpha = \frac{b^2}{a^2};$$

that is when

$$\sin \alpha = \frac{b^2}{a^2} - 1 = \frac{b^2}{a^2} e'^2,$$

or

$$\alpha = \text{arc} \sin \left(\frac{b^2}{a^2} e'^2 \right).$$

A casual examination will show, that the ellipsoid may be derived from the oblate spheroid by the method of Isogonic Transformation. In fact, the method may be applied to any figure through its equation, or, simply by graphics.

There is no indication at present that this method of transformation admits of any practical application.

Issued May 16, 1901.

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Transactions of The Academy of Science of St. Louis.

VOL. XI. No. 4.

THE RELATION OF DIRECT TO REVERSED PHOTOGRAPHIC PICTURES.

FRANCIS E. NIPHER.

THE SPECIFIC HEAT OF GASEOUS NEBULAE IN GRAVITATIONAL CONTRACTION.

FRANCIS E. NIPHER.

Issued June 7, 1901.

THE RELATION OF DIRECT TO REVERSED PHOTOGRAPHIC PICTURES.*

Francis E. Nipher.

In former papers in these Transactions † the author has given a partial exposition of the results of developing photographic pictures in the light. These results were reached in the course of a long series of experiments, in which the films were acted upon by electrical discharge. It was found that the most rapid plates might be exposed to daylight for a week, and that contact electrographs of coins might then be produced in a well-known way. It was also found that these pictures might be developed in the light, and that for exposures to electrical action with a Holtz machine for several minutes, these pictures were negatives. The parts of the film most exposed to electrical action came out dark when developed either in the dark-room or in the light, but those developed in the light were clearer and gave less trouble from fog. The significance of this was not then fully realized, and there remain yet many points to be cleared up by further study. Since that time specially treated plates have yielded negatives in the light from ordinary camera exposures and they showed a marked improvement when the light was turned on. But the method is not as yet under sufficient control so that the results can be obtained except at rare intervals.

The results given in the former paper seem to have been misunderstood by many, who have apparently supposed that the author was not aware of the fact that photographic positives had long been known as a result of developing greatly over-exposed plates. This was expressly stated in the first

* Presented and read in abstract before The Academy of Science of St. Louis, April 15, 1901.

† Trans. Vol. X., Nos. 6 and 9.

paper referred to, and it was clearly pointed out that development in the light was the feature to which attention was invited.

In the present paper the conditions which yield direct and reversed pictures will be given. The work has been restricted to Cramer's "crown" plate, and the developer used was hydrochinon. The plates were all exposed in a printing frame either to the light of an incandescent lamp or to daylight. The pictures were all printed from the same lantern slide, or positive, so that the direct pictures are all negatives, and the reversed are all positives.* The over-exposed negative and the under-exposed positive require the same kind of treatment. A restrainer must be used, whose function is to keep away the fog. The fog is incidental to an approach to a zero condition in which the plate will be blank. The restrainer does not change the character of the picture as regards positive or negative. It is not necessary to use it for what are called normal exposures, when negatives are developed in the dark room, nor for normal exposures when positives are developed in the light. The amount of restrainer used must increase as the zero condition is approached. The amount needed may be as great as a twelfth of the entire bath in ten per cent. solution of potassium bromide, and this may be supplemented by the addition of from two to five drops of saturated solution of sodium hyposulphite. When the picture to be developed is a landscape with modulated lights and shadows, any exposure from normal to more than ten million times over-exposed may be developed in the dark-room. As the zero condition is reached, the strongest highlights will reverse, and the other parts of the picture will locally reverse as greater exposures are given, but without complete loss of detail. There will be incongruities in light and shadow, and each local detail will have at a certain exposure, a minimum of distinctness. A picture in which the shadows are alike, and likewise the lights, will develop a blank at the zero con-

---

* This method of exposure was adopted in order to secure known conditions of illumination. For some of the longer exposures, a 300-candle Packard incandescent lamp was used, and was found very satisfactory. This lamp was kindly furnished by the manufacturers.

dition. This would be the case if a punched stencil in cardboard were printed upon a sensitive plate.

The zero condition does not seem to be affected by varying the strength of the bath. If the plate be first placed for a minute in a normal bath, it may then be transferred to and developed in a bath as weak as one-tenth the normal strength. The positive and negative features are then the same as when developed in the normal bath. If the plate is first placed in the weak bath, the solution does not wet the film uniformly, and the plate appears as if it had been attacked by a painter's brush while the gelatine was soft.

There is little need to lose any valuable landscape exposure entirely if the plate is from the first treated as an over-exposed plate, until its condition is known.

The plate from which the printing was done is reproduced in Fig. 1, Plate 2.* When exposed for one second at a distance of a meter from a 16-candle lamp a normal negative results from development without restrainer. When the exposure has been increased to 53 m. 20 s. or 3200 seconds, the strong light across the walk to the left of the picture begins to reverse, and appear white as a positive. The original slide does not quite cover the sensitive plate below. On a narrow strip along the left edge of the picture, the plate is fully exposed to the light. This part also begins to reverse at the same time as the high-light mentioned. In diffuse daylight ten feet from a south window when the sky is as clear as it usually becomes in St. Louis, during the winter, the picture will begin to reverse with sixteen seconds of exposure. This time varies somewhat with variations in illumination and only rough approximations are possible. This daylight is therefore actinically about 200 times as active as one lamp-meter, which required 3200 seconds to produce the same result. As the exposure increases, other parts of the picture reverse. The light on the monk's lap will finally reverse, and appear white, while the part below in shadow will also appear white, because it is still a negative.

---

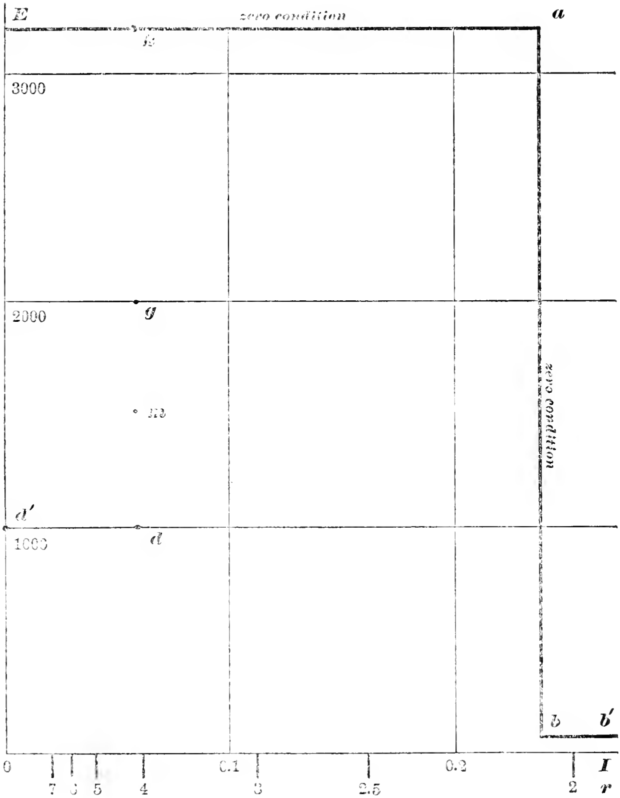
* The picture was not formed symmetrically on the plate, and the transparent border is lacking on one side of the picture. The picture was obtained by an artist friend in Southern California.

Such a result is shown in Fig. 11, Plate 7. The penumbra which separates light and shadow appears then darker than either the lighter or the darker areas adjoining. Nevertheless the whole figure of the monk shown in the foreground is sharply differentiated from the background. The dense foliage to the right of the picture is still a negative, while the entire left half of the picture has reversed. When the exposure time has increased to about ten minutes of daylight, or 120,000 lamp-meter-seconds, the last detail of the picture has just reversed or is about to reverse. This part is the deep shadow among the foliage in the right of the picture. In Fig. 12, Plate 7, the picture is all reversed, excepting a small area of the darkest foliage.

When the exposure has been increased to two hours, a sharply defined positive, yielding a good print, is yet obtained. It is, however, somewhat dense, and prints slowly. The picture from this exposure is reproduced in Fig. 13, Plate 8. The exposure for this plate is equivalent to $7200 \times 200 =$ 1,440,000 lamp-meter-seconds, or over sixteen lamp-meter-days.

When instead of developing the exposed plate in the dark room, it is developed at a distance $r =$ seven meters below a 16-candle lamp, the plane of the filament being horizontal, a similar series of pictures is obtained as the exposure time increases. The picture begins to reverse exactly as in the dark room, when the exposure in lamp-meter-seconds is 3200. All exposures less than this give negatives, of surprising merit. The positive or reversed pictures having a greater exposure than 3200 cannot be distinguished from those made in the dark room. In the diagram representing the conditions of exposure and development, the co-ordinates are exposure E, in lamp-meter-seconds, and illumination, I, in lamp-meters, of the developing bath. The value of I is $\frac{1}{r^2}$, where r is the distance of the bath from the 16-candle lamp. The value I is laid off on the horizontal axis of the diagram, and the numbers representing distances r, ranging between 2 and 7 meters, are indicated along the axis I at places on the scale which those distances determine. For example where $r = 2$ meters,

DIAGRAM I.



Ordinates represent exposure in lamp-meter-seconds. Lamp = 16 candle power.
Abscissae represent illumination of the plate while in the developing bath, in lamp-meters.
The rectangular area within the zero line, covers the conditions yielding negatives. External to this line is the region of positives.

the value of I in lamp-meters is $\frac{1}{2^2} = 0.25$. The vertical axis E, where $I = 0$, corresponds to $r = \infty$. This vertical axis therefore represents increasing exposures in the dark room.

For all values of I less than $\frac{1}{(2.05)^2} = 0.238$ the picture begins to reverse when the exposure time is 3200 seconds, exactly as has been described for dark room development. This value of I is a critical value. When the developing plate has this illumination, a zero plate is obtained for all exposures between 53 and 3200 lamp-meter-seconds. The zero line which for smaller values of I was the horizontal line Ea, of the diagram, drops straight down from a to b. As this line is approached from the negative side, the picture becomes more and more obscure, and on reaching it the plate is blank, with the exception of a few faint isolated features here and there, some of which appear to be positive and some negative. If I is made slightly greater than this critical value, the picture wholly reverses and becomes positive as soon as E exceeds 53 seconds. For slightly smaller values the picture is a poor negative. The line $b\ b'$ is a sharp line of separation between positive and negative results, and no mongrel pictures are produced in the transition. The line $b\ b'$ is not horizontal. When the picture is developed at a distance $r = 1$ meter, for which $I = 1$, faint positive pictures are obtained with an exposure of 25 lamp-meter-seconds. Thus far it has been found impossible to develop any negatives in this light. The zero line evidently approaches the axis I for illuminations greater than the critical value $I = 0.238$. For daylight development the picture evidently starts from a positive condition, just as for small values of I it starts from a negative condition. When the plate is illumined with the critical illumination there is probably some condition of chemical instability which should render the plate photographically sensitive to feeble influences which under other circumstances might have no discernible effect. This might apply to electrical oscillations. This critical condition has been very carefully studied photographically, and plates have been produced along the entire range represented by the line $a\ b$, both on the negative and on the positive side.

The area on the diagram representing the conditions where good photographic positives can be produced has not yet been adequately explored. An attempt was made to form an exhibit of developed plates which would show by inspection the results obtainable with various exposures E, and illuminations I of the plate while developing. The plates were laid upon a large table at points determined by the co-ordinates E and I. In order to properly represent dark-room work, the scale of E should be at least one meter for one lamp-meter-second. Ordinary dark-room work with ordinary over-exposures would then require a table a few meters in length. The time of exposure which will yield good positives has, however, been found so large that the plan proved impracticable. Fig. 15, Plate 9, is a reproduction of a picture which had an exposure of 16 hours to diffuse daylight. The value of E in the diagram was about $16 \times 3600 \times 200 = 11,520,000$ lamp-meter-seconds. This would be equivalent to a continuous exposure of four months to a 16-candle lamp at a distance of one meter. The position of this plate on the exhibition table would be at a distance $E = 11,520$ kilometers or about 6,900 miles from the axis I. The plate was developed in a glass tray in diffuse daylight with reflected light thrown up through the bottom of the tray. The value of I was therefore over 200, which is about 800 times the value that could be represented in the diagram. With these long exposures the best results have been obtained by reflecting light through the bottom of a glass tray, while the plate is being developed. If this cannot be done, the plate should be lifted out of the liquid at intervals, and the bottom should be exposed to the light. Fig. 16, Plate 9, shows a trace of two ribs in the bottom of the developing tray which cut off part of the light.

These long exposures show wonderful detail in the darker shadows. They show with clearness details that are barely distinguishable in the original plate from which the printing was done. Referring to the plates,

Fig. 1 is a positive, from which all the printing was done.

Fig. 2 is a negative, printed from 1, with an exposure of one lamp-meter-second, $E = 1$, and developed in the dark room. These conditions are represented by a point in the diagram which is practically at the origin 0.

Fig. 3 is a negative having an exposure $E = 1000$, and developed in the dark room. The point in the diagram is marked d'.

Fig. 4, is a negative having an exposure 1000, and developed at a distance $r = 4$ meters below a 16-candle lamp. The illumination is $I = 0.0625$. The point in the diagram thus determined is marked d.

Fig. 5 is a negative having an exposure $E = 1500$, and developed exactly like No. 4. The point in the diagram is marked m.

Fig. 6 is also a negative, having an exposure $E = 3200$, and developed under the same conditions as Figs. 4 and 5. This picture has just begun to reverse. The light on the walk just beyond the pan, has begun to turn white. The picture is rather dense, but the details are sharp. The bright strip around the picture has also become lighter. Point k in the diagram represents the conditions.

Fig. 7. The plate here reproduced has had the same exposure as the last, but it was developed one meter below three 16-candle lamps. Hence $I = 3$. The diagram does not extend beyond the value $I = 0.25$.

Fig. 8. This plate had an exposure $E = 3200$ like the last, but the value of $I = 100$.

Fig. 9. The exposure was $E = 24000$ and the plate was developed in daylight where $I = 200$. The plate is wholly reversed.

Fig. 10. Exposure $E = 36000$, $I = 200$. This picture is a clear positive, and was developed without any restrainer.

Fig. 11. This plate had an exposure 60000, and was developed 2.25 meters below a 16-candle lamp. The value of $I = 0.197$. This is somewhat less than the critical value of I, represented by the line ab in the diagram. The picture has only in part reversed, although the plate last described, with an exposure only a little more than half as much, was fully reversed, because of the larger value of I.

Fig. 12. This plate had an exposure $E = 120,000$.

The value of $I = 0.0625$. The only part of the plate which is still negative is a small area in the dense foliage in shadow, on the right of the picture.

Fig. 13. Exposure $E = 1{,}440{,}000$. $I = 0$.

This picture is completely reversed.

Fig. 14. This plate had the same exposure as the last, but was developed in daylight where $I = 200$.

Fig. 15. Exposure 5,000,000. $I = 200$.

The details in the dense shadows are admirably shown in this picture. The exposure was seven hours to diffuse daylight in front of an inclined skylight about ten feet square. The exposure was to a northern sky.

Fig. 16. This exposure was made like the last one, but lasted for sixteen hours on two days. The plate was developed in the same light, with a mirror reflecting light upward upon the under side of the plate. The traces of two ribs in the bottom of the glass tray, are shown on the plate.

Fig. 17. This picture is from the negative shown in Fig. 2, Plate 2. It is a reproduction of a print from that negative, which was made by ordinary methods. It is to be compared with Fig. 18, made from the same original as Fig. 16, which is from an exposure 11,500,000 times as great.

A number of good pictures have been developed in direct sunlight, but they have been lost or destroyed, and it has since been found difficult to produce as good ones as were formerly made. There is strong evidence that there is a discontinuity in the conditions of sunlight development like that shown by the zero line at the critical illumination. One difficulty in the study of this subject, is the extreme variability of sunlight. The actinic value of sunlight is also enormous compared with the standard illumination used in this work. An exposure of about a quarter of a second is greater than an exposure of 120,000 seconds at a distance of one meter from a 16-candle lamp. The developing of good pictures in direct sunlight is therefore in an uncertain condition as yet, and is receiving further study.

If the plan of laying the developed plates down upon a table at points determined by E and I, had proved practicable, it would have been possible to draw on the diagram, lines passing through points where the plates have equal excellence. These lines might be considered to be contour lines surrounding the summit of a surface. This summit, representing the maximum of excellence of negatives would be on the vertical axis, E, and very close to the origin. It would correspond to normal conditions for dark-room work. The surface would sink to a minimum along the zero line shown in the diagram, and would then rise again in the immense field representing the conditions under which positives may be developed. The conditions of maximum excellence for positives are as yet unknown, but the best pictures yet obtained, which seem to be as near perfect as could be wished, had exposures of two and a half minutes in strong diffuse light just outside of direct sunlight at a south window. This illumination was probably about 400, on the scale used in this paper. The pictures were developed at the same point.

In the pictures here presented the plates have all received uniform treatment. No shading of highlights has been done. In the etching during the half-tone reproduction all parts of the plate have been treated alike.

In reproducing Fig. 6 it was found that on account of a muddy background effect in those parts of the plate which were about to reverse, the original did not submit itself readily to the half-tone process. Details which could be clearly seen could not be satisfactorily reproduced. The plate was therefore re-photographed by ordinary means, and from this plate a print was made which has been reproduced in half-tone.

This plate having an exposure of 3200, marks the beginning of reversal. All exposures greater than this lie above the horizontal zero line. The picture does not wholly reverse until the exposure has reached 120000. This broad belt of mongrel effects extends along the whole length of the horizontal zero line, from dark-room conditions to critical illumination. The upper limit of this belt will of course vary with different plates, depending upon the density of the plate in the deepest shadows.

So soon as the plate is developed in a light stronger than the critical value, no mongrel effects appear, and the exposure time for a plate yielding zero effects drops at once to

0.016 of 3200. In these stronger illuminations is therefore a field of promise for positive photography with short exposures. It may perhaps require a modification of the developer, the plate emulsion or both, in order to secure the best attainable results.

In one of the figures, the pencil marks put on in the dark room do not agree with the ink marks. The latter are correct.

Issued June 7, 1901.

THE SPECIFIC HEAT OF GASEOUS NEBULAE IN GRAVITATIONAL CONTRACTION.*

Francis E. Nipher.

In former papers in these Transactions † the author has discussed the conditions of equilibrium in an infinite mass of gas, symmetrically arranged around a centre towards which it gravitates.

Assuming at any instant a uniform temperature T_0 throughout the mass, the density δ_0 of the gas and the pressure P_0 at a distance R_0 from the centre is ‡

$$\delta_0 = \frac{C\,T_0}{2\pi k R_0^2} \tag{1}$$

$$P_0 = \frac{C^2\,T_0^2}{2\pi k R_0^2} \tag{2}$$

where C is the constant for the gas, and k is the gravitation constant. The mass within a radius R_0 is as Woodward showed

$$M_0 = \frac{2\,C\,T_0 R_0}{k}. \tag{3}$$

Let the entire nebulous mass contract so that the radius of the spherical mass M_0 diminishes to R, and each element of mass initially, distant r_0 from the centre shall finally be distant r, and satisfying the condition

$$\frac{r_0}{r} = \frac{R_0}{R} = \rho.$$

* Presented and read by title before The Academy of Science of St. Louis, May 20, 1901.

† Trans. Vol. IX. Nos. 4 and 7.

‡ See Woodward's paper. Trans. Vol. IX. No. 3.

A new state of equilibrium will result in which

$$\delta = \frac{CT}{2\pi k R^2} \qquad (4)$$

$$P = \frac{C^2 T^2}{2\pi k R^2} \qquad (5)$$

$$M = \frac{2CTR}{k} = M_0.$$

The relation of final to initial temperature was shown to be

$$T = \rho T_0.$$

It follows that at the surface of the mass M,

$$\delta = \rho^3 \delta_0,$$

and

$$P = \rho^4 P_0.$$

The work done upon the spherical mass by the superposed gravitating mass while the radius shortens by dR is

$$dW = -4\pi R^2 P dR$$

$$= -\frac{2C^2T^2}{k} dR.$$

In this equation

$$T^2 = \rho^2 T_0^2 = \frac{R_0^2 T_0^2}{R^2}.$$

Inserting this value of T^2 in the last equation, the work done upon the spherical mass while the radius shortens from R_0 to R is

$$W = -\frac{2C^2T_0^2R_0^2}{k}\int_{R_0}^{R}\frac{dR}{R^2} = \frac{2C^2T_0^2R_0}{k}(\rho - 1). \qquad (6)$$

Let H represent the heat produced in the mass M during this operation, J, the mechanical equivalent of heat, and s the specific heat of the gas. Then

$$W = JH = Js\frac{2CT_0R_0}{k}(T - T_0)$$

$$= Js\frac{2CT_0^2R_0}{k}(\rho - 1). \qquad (7)$$

By equating (6) and (7) the specific heat during this operation in which pressure, volume and temperature all change is

$$s = \frac{C}{J}. \qquad (8)$$

This result is the well-known expression for the difference between the specific heat at constant pressure and the specific heat at constant volume.

The value of J in C. G. S. units and Centigrade degrees is 4.19×10^7.

The annexed table gives for a few of the "permanent" gases, the values of C, and of the specific heat s of such gases when forming this gravitating cosmical mass in isentropic compression.

The values of C are computed from Regnault's determinations of δ.

SUBSTANCE.	C.	s.
Hydrogen	4.140×10^7	0.988
Air	2.868×10^6	0.0685
Oxygen	2.594×10^6	0.0619

In the cylinder of the Carnot engine where gravitation is not involved, and where the pressures are uniform, the specific heat of isentropic compression, computed as has been done for this nebula, is the specific heat of constant volume.

During this operation the average condition of the gas within radius R changes, and this change may be represented by a moving point on the thermodynamic surface whose equation is

$$PV = CT.$$

When a gas is heated either under constant pressure or constant volume, the moving point on this surface traces a straight line in space. There are, of course, an infinite variety of operations to which the gas may be subjected, in which the point representing the condition of the gas may trace out in each case some definite path on the surface referred to. Each operation will involve some value for the specific heat.

The average density of the mass M is at all times three times the density at its surface. Hence calling V_0 the initial, and V the final volume of the spherical mass, the law of gases gives the equations

$$P_0 V_0 = \frac{1}{3} C T_0 M \qquad (9)$$

$$PV = \frac{1}{3} CTM. \qquad (10)$$

These equations may also be obtained from (2) and (5) by multiplying by the volumes of the respective spheres having radii R_0 and R. The right hand member is then reduced to the form given, by introducing the value of M_0 or the equal value M from (3), or the equation which follows (5).

Since

$$P = \rho^4 P_0 = \frac{P_0 T^4}{T_0^4},$$

the value of P in the last equation may be eliminated. The two equations then give

$$T^3 V = T_0^3 V_0 = \frac{4}{3} \pi R_0^3 T_0^3$$

which by (3) becomes

$$T^3 V = \frac{\pi}{6} \left(\frac{Mk}{C}\right)^3. \qquad (11)$$

The point traces upon the surface a path, which projects on the co-ordinate plane T, V, in a curve of which (11) is the equation.

Eliminating V in (10) and (11)

$$P = \frac{2C^4}{\pi M^2 k^3} T^4. \qquad (12)$$

In like manner by the elimination of T in the same equations

$$PV^{\frac{4}{3}} = \left(\frac{\pi}{6}\right)^{\frac{1}{3}} \frac{M^2 k}{3}. \qquad (13)$$

These equations represent projections of the path on the other co-ordinate planes.

The relations involved in (11), (12) and (13) were published by Ritter* in 1878, in the form

$Pv^{\frac{4}{3}} = \text{const.}$, $Tv^{\frac{1}{3}} = \text{const.}$, $\frac{T^4}{P} = \text{const.}$ The equations which precede determine the value of these three constants in terms of the mass M of the gas, the constant C for the gas, and the gravitation constant k.

The preceding equations may be used in determining the total heat produced in the shrinkage of a given mass M, from infinite dimensions to a sphere of radius R, the distribution of pressure throughout the mass being as previously assumed. If the value CT be eliminated in the general equations for P and M, the pressure at the surface of the mass M whose radius is R, is found to be,

$$P = \frac{M^2 k}{8\pi R^4}.$$

The work done on this mass by superposed layers while the radius shortens by dR is

$$dW = -4\pi R^2 P dR.$$

Hence

$$W = -\frac{M^2 k}{2} \int_{\infty}^{R} \frac{dR}{R^2} = \frac{M^2 k}{2R}.$$

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* Annalen der Physik und Chimie. Bd. V. S. 550.

Here $M\sqrt{k}$ is the mass in astronomical units. The initial temperature, when $R = \infty$ must be assumed to be zero. In its final condition the temperature of the mass has risen to T. The specific heat has been shown to be $\frac{C}{J}$. Hence the total heat produced within the mass M during the operation was $\frac{MCT}{J}$. The work-equivalent of this heat is

$$W = MCT.$$

Equating the two values of W, and solving for T,

$$T = \frac{Mk}{2CR}.$$

This equation is identical with (3) and the result merely shows the nature of the conditions which are involved in the equations which precede.

The last equation was originally deduced by C. M. Woodward in the paper previously cited. It was deduced as a condition of statical equilibrium in a cosmical mass of gas of uniform temperature T. Woodward denied that it could apply in gravitational contraction, or even that gravitational contraction was possible.

It is certainly true that the equations given in this discussion involve at each point in the gaseous mass, a condition of balanced forces. It is as though a weight on a piston rod is continually and automatically increased as isentropic compression proceeds, and at the precise rate which continuous isentropic compression demands.

If the infinite space occupied by this cosmical mass of gas, may be considered the first of an infinite series of infinite spaces having perhaps increasingly higher orders of magnitude, we might suppose that heat developed in the nebula by compression may dissipate by radiation, into the realms beyond. If heat could thus be abstracted from all parts of the mass with equal facility, the conditions resulting would certainly be different from those which would result if the radiation were greatest from those parts most remote from the centre. The real conditions will then be determined by the rate at which heat can be taken from the mass. The loss of heat will still result in a rise of temperature of the radiating mass and a contraction in volume. At the same time this loss of heat from the mass at a greater or less rate will determine the time required for the nebula to pass through its history of gravitational contraction.

In this discussion the conditions are somewhat special in their character, and the equations are not in a form adapted to other and general conditions. If any initial condition be assumed in which the temperature of the mass is T_0, and if the mass contract so that the ratio of contraction is everywhere $\rho = \frac{r_0}{r}$, then equations (4) and (5) may be written

$$\delta = \frac{C T_0 \rho}{2\pi k R^2} \tag{14}$$

$$P = \frac{C^2 T_0^2 \rho^2}{2\pi k R^2}. \tag{15}$$

These equations give the pressure and density at any point distant R from the centre, after any contraction ρ has taken place.

The value of g at any point within the mass will be

$$g = \frac{2 C T_0 \rho}{R} \tag{16}$$

and the mass internal to any point distant R will be

$$M = \frac{2 C T_0 R \rho}{k}. \tag{17}$$

The final temperature throughout the mass will be

$$T = \rho T_0. \tag{18}$$

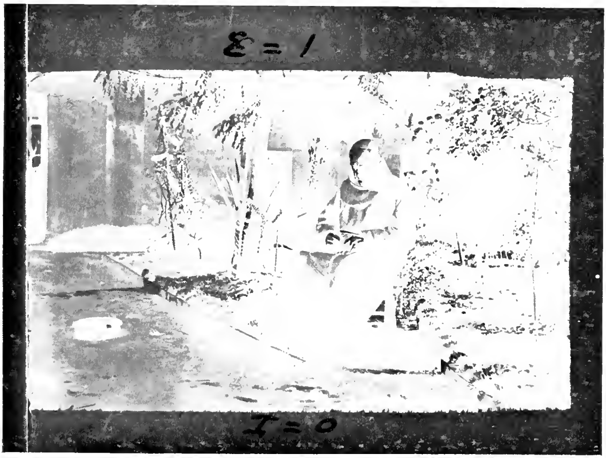
If, for example, the ratio of contraction ρ, be made 4, then at any fixed point in space distant R, the values of g, δ and M will be made four times as great, while the pressure will become sixteen times as great.

To find the points where the original values will exist, these equations indicate that the density after this contraction, will have its initial value at a distance $2R$. The initial pressure will be found at a distance $4R$.

The weight of a gramme, g, will have the initial value at a distance $4R$. The mass internal to the point considered will have the initial value at a distance $\frac{1}{4}R$. In these last equations the variables ρ and R are entirely independent.

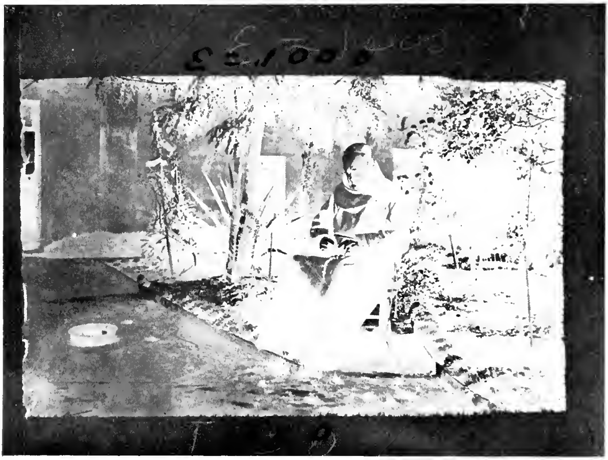
Issued June 7, 1901.

1. THE ORIGINAL.



2. EXPOSURE, 1. ILLUMINATION, 0.

DIRECT AND REVERSED PHOTOGRAPHY.



3. Exposure, 1,000. Illumination, 0.

4. Exposure, 1,000. Illumination, 0.063.

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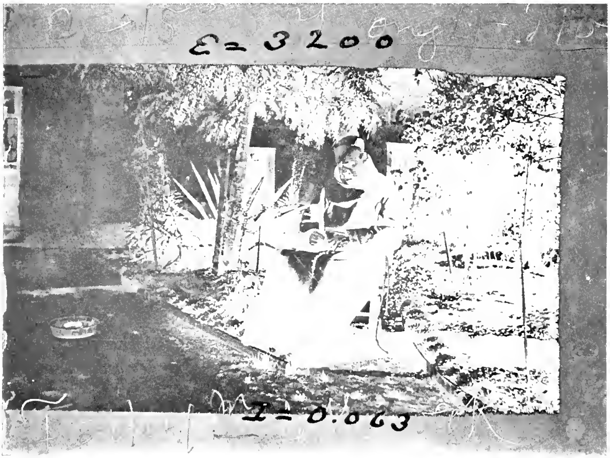
5. EXPOSURE, 1,500. ILLUMINATION, 0.062.



6. EXPOSURE, 3,200. ILLUMINATION, 0.063.

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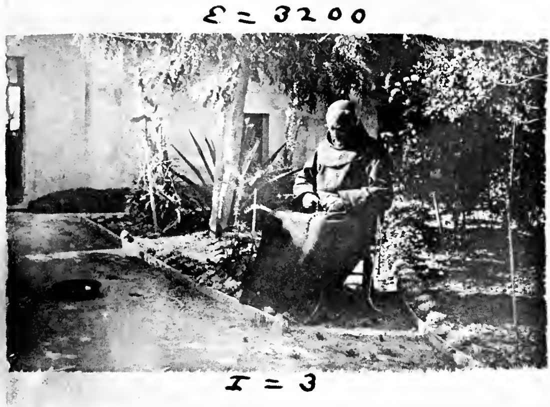

7. Exposure, 3,200. Illumination, 3.

8. Exposure, 3,200. Illumination, 100.

DIRECT AND REVERSED PHOTOGRAPHY.

9. Exposure, 24,000. Illumination, 200.

10. Exposure, 36,000. Illumination, 200.

DIRECT AND REVERSED PHOTOGRAPHY.

11. EXPOSURE, 60,000. ILLUMINATION, 0.197.

12. EXPOSURE, 120,000. ILLUMINATION, 0.063.

DIRECT AND REVERSED PHOTOGRAPHY

13. Exposure, 1,440,000. Illumination, 0.

14. Exposure, 1,440,000. Illumination, 200.

DIRECT AND REVERSED PHOTOGRAPHY.

15. Exposure, 5,000,000. Illumination, 200.

16. Exposure, 11,500,000. Illumination, over 200.

DIRECT AND REVERSED PHOTOGRAPHY.

17. FROM A NORMALLY EXPOSED PLATE (FIG. 2).

18. FROM A PLATE OVER-EXPOSED 11,500,000 TIMES (FIG. 16).

DIRECT AND REVERSED PHOTOGRAPHY.

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Transactions of The Academy of Science of St. Louis.

VOL. XI. No. 5.

THE ADVANCE OF ZOÖLOGY IN THE NINETEENTH CENTURY.

GEORGE LEFEVRE.

Issued July 3, 1901.

THE ADVANCE OF ZOÖLOGY IN THE NINETEENTH CENTURY.*

George Lefevre.

The task of reviewing in the limits of a single lecture the progress in the nineteenth century of zoölogy, a science which has undergone by far the greater and most important part of its development within the century and which to-day presents a vast array of fact and theory, is one of embarrassment of riches. I can only attempt to bring to your attention a few of the more conspicuous achievements of the century in the field of zoölogy; to speak briefly of the dawn of the science; and to indicate the trend of its progress at the present time. In so doing I shall trace the advance along four great lines of zoölogical development, which, although they often meet and become confluent, receiving from and giving impetus and material to each other, have, nevertheless, advanced more or less independently. It is thus possible to follow the thread continuously through each. These four lines are as follows:

1. Morphology, or the study of form and structure, including systematic zoölogy.

2. Evolution, or the application of evolutionary principles to organic nature.

3. The Cell Doctrine, or the doctrine that living things are made up of elementary vital units, termed cells.

4. Experimental Morphology, or the investigation of the causes underlying the forms and activities of living things, the study of which has been pursued through the experimental method. This last line belongs to a very recent date, its main development having taken place within the past decade.

* An address delivered before The Academy of Science of St. Louis, May 20, 1901.

I. MORPHOLOGY.

In Aristotle, who may justly be called the "Father of Zoölogy," we find the first dawn of morphology, which he advanced far beyond the fragmentary knowledge of his predecessors. Although his errors were many and often grotesque, it is still a matter of wonder that his observations upon the structure and activities of animals possessed such a high degree of accuracy; and strange to say, some of his discoveries have only received confirmation within the nineteenth century, as, for example, that many sharks are viviparous and their embryos are attached to the maternal uterus by means of a nutritive contrivance, the placenta.

Although Aristotle did not propose a definite classification of animals, he recognized certain main groups, distinguishing them by important characters and assigning to them descriptive names. He separated all animals into two great divisions, the ἔναιμα, or animals with blood, and the ἄναιμα, or bloodless animals, that is, those with no blood or with colorless blood. These groups correspond to the Vertebrata and Invertebrata, respectively.

Among Aristotle's successors and other writers of antiquity we find little of value, and even those who wrote on zoölogy at all represent a retrogression from the stage of advancement which Aristotle had attained. This is true of Pliny, who, while contributing no original observations of his own, included much that was fabulous in his compilations of the writings of others, and replaced Aristotle's natural classification by a purely arbitrary and unnatural one, dividing animals into those that fly, those that live on land, and those that live in the water.

The Middle Ages followed with their blight upon the natural sciences, and during this long period of darkness the annihilation of observation and investigation of natural phenomena was almost complete. It is true that the Schoolmen concerned themselves with labored and learned discussions of such questions as "how many teeth has the horse?" but so long as their method was one of *a priori* argument and no one thought of looking into a horse's mouth to find out, the advance of zoölogy was not likely to make rapid strides. The state of mental stagnation and perversion in regard to animal life during this period is well indicated by the Physiologus or Bestiarius, names given to a class of books of great popularity during the Middle Ages which served as encyclopedias of the zoölogy of the time and which fairly represent the attitude of mind then existing toward animal life. The books contain absurd and symbolical descriptions of about seventy animals, many of which are creatures of fable, as, for example, the dragon, the unicorn, and the phoenix; and the stories are nearly all written for the purpose of illustrating some religious or moral teaching. Witness the following: "The unicorn has but one horn in the middle of its forehead. It is the only animal that ventures to attack the elephant; and so sharp is the nail of its foot, that with one blow it rips up the belly of that most terrible of all beasts. The hunters can catch the unicorn only by placing a young virgin in the forest which it haunts. No sooner does this marvelous animal descry the damsel, than it runs towards her, lies down at her feet, and so suffers itself to be taken by the hunters. The unicorn represents our Lord Jesus Christ, who, taking our humanity upon him in the Virgin's womb, was betrayed by the wicked Jews, and delivered into the hands of Pilate. Its one horn signifies the gospel truth, that Christ is one with the Father."

After this legendary period, it was not until 1552 that the darkness was broken by a ray of light, and interest in scientific investigation awoke. In that year appeared the work of the Englishman, Wotton, "De Differentiis Animalium," which was essentially a return to Aristotle and a rejection of the absurdities of the Middle Ages. To Aristotle's classification he added one other group, under the ἄναιμα, namely, the Zoöphyta, or "plant animals," in which he included Holothurians, Star-fishes, Medusae and Sponges.

To about the same period belong the writings of Conrad Gesner, Ulysses Aldrovandi of Bologna, and Johnstone, whose works, however, are a more or less critical compilation of stories, records and pictures of animals, representing the knowledge of zoölogy of the time and gathered from the great libraries of Europe and from reports of adventurous travelers in foreign lands.

The great awakening which spread over Europe in the sixteenth century after the long intellectual paralysis of the Middle Ages led to the revival of independent observation of natural phenomena. It was but natural that interest in investigation should have centered in the great universities, and, owing to the connection of medicine with these seats of learning, attention was first given to the study of the structure and functions of the human body and of the higher animals. Comparative anatomy, having thus arisen in connection with the study of medicine, was developed in the medical schools and, in fact, until a very recent date, it has been almost universally assigned to the Medical Faculty, especially in Europe. The spirit of inquiry which now became general, showed itself in the anatomical schools of the Italian universities, and later at Oxford, and a great impetus was given to observation and experiment by the learned scientific academies and societies which sprang up over Europe in the seventeenth century.

All through the Middle Ages the sum-total of medical and anatomical knowledge was contained in the works of Galen whose authority had remained unquestioned from the time of the second century. It was not until the middle of the sixteenth century that the modern development began, and the numerous errors of Galen were pointed out in the light of the knowledge which was then acquired from a scientific investigation of the human cadaver. Much repugnance had previously been shown to dissection of the human body, and many and gross errors had been in existence since the time of Galen from an unwarranted application to human anatomy of discoveries made upon the lower animals.

The great names of the sixteenth century in anatomical investigation are Harvey, the discoverer of the circulation of the blood, and the Italians, Vesalius, Eustachius, Fabricius, Riolan and Severinus.

Later on, in the seventeenth century, Malpighi, Swammerdam and Leeuwenhoek introduced the microscope, and investigation was at once carried into the field of microscopical anatomy, with the resulting discovery of the red blood-corpuscles in vertebrates, the cross-striation of muscular fibre, the fibres of the lens of the eye, the spermatozoön, and many other important facts of microscopical structure.

In the latter part of the sixteenth century and the beginning of the seventeenth, interest had arisen in the structure and life-history of particular groups of animals, the development of which was greatly stimulated by the discovery and description of interesting forms of animal life from distant countries. There soon arose a body of facts which made possible a systematic classification of animals and plants, based upon their anatomical structure, which was to reach its culmination in the work of the Swedish naturalist, Linnaeus. The chief name between the time of Gesner and Linnaeus in systematic zoölogy is that of John Ray, who paved the way for his illustrious successor and who is prominent from the limitation which he set upon the term species previously only vaguely applied. The meaning which he placed upon the term remained until Darwin gave it a new significance.

Linnaeus was born in 1707 and died in 1778, and in his great work, the "Systema Naturae," first published in 1735 and passing through twelve editions before his death, he laid the foundation of modern systematic zoölogy. In place of loose and rambling descriptions he introduced concise, brief diagnoses, adding numerous discoveries in the anatomy of plants and animals and descriptions of many new species. But his chief merit lies in the fact that he inaugurated a method of classification which practically created systematic zoölogy and botany in their modern form. Before Linnaeus long, many-worded names had been used and no uniformity existed, but by the introduction of his system of binomial nomenclature it became possible to speak of any given animal or plant with accuracy and to express in a single phrase resemblances and differences between species. Hitherto much confusion had arisen from the use of common names in the scientific world, and furthermore from the fact that one and the same animal or plant might have different names, or different animals and plants the same name. In Linnaeus' binomial system this was entirely obviated. The first name, usually a noun, denotes the genus; the second, usually an adjective, the species. Thus, *Canis familiaris*, *Canis lupus* and *Canis vulpes* indicate the dog, the wolf and the fox respectively, and moreover, that they all belong to a common genus of dog-like animals, though representing different species within the genus. He further grouped his genera into orders and the orders into classes, and into these four divisions, classes, orders, genera and species he arranged the entire animal kingdom, like the subdivisions of an army, the greater group containing several of the lesser. Although Linnaeus treated of a far larger number of animals than any of his predecessors, nevertheless, his classification as a whole was a retrogression from Aristotle's. He divided animals into six classes; namely, Mammalia, Aves, Amphibia, Pisces, Insecta and Vermes. The first four correspond to Aristotle's ἔναιμα, or blood-containing animals, the Insecta and Vermes to the ἄναιμα, or bloodless animals; but among the latter he does not recognize as many distinct groups as did Aristotle, and hence, we may regard the classification as a backward step.

Linnaeus adopted Ray's conception of species, regarding it as a fixed, permanent, objective reality, and maintaining that species were created as such in the beginning by the Infinite Being, and that just as many species are present as have been from the first. This erroneous conception of species was destined to last for over a century, and only disappeared finally when the acceptance of the descent-theory became general.

Great as was the service rendered by Linnaeus' reform in classification, it nevertheless contained the germ of a one-sided development, for there soon arose a great array of systematists who, in their zeal and enthusiasm for naming and classifying animals and plants, made this the end and aim of the study of zoölogy, and failed to appreciate the obvious truth that the work of classification is merely an aid to the investigation of the fundamental problems and not a goal in itself. The ultimate purpose of the science, namely, the investigation of the nature and causes of living things, was utterly lost sight of by Linnaeus and his followers, and interest in anatomy, physiology and embryology lagged far behind. The narrow and false aim thus established in large measure dominated the study of zoölogy for many years afterwards and resulted in a dry, spiritless investigation which during the first half of the nineteenth century had brought zoölogy into much disrepute among thinking men.

Widespread as was the influence of the species-maker during the latter part of the eighteenth century and first half of the nineteenth, he nevertheless did not hold an undisputed field. Although it was not until the dawn of the Darwinian Era that his doom was finally sealed, there had been many voices lifted in protest against the purely empirical method of the systematists, and there soon arose in revolt against the Linnaean School a large number of philosophical zoölogists who endeavored to bring order into the chaos of the vast amount of accumulated raw material. There thus sprang up over Europe the so-called nature-philosophers, most notably and ably represented by Erasmus Darwin, Lamarck, Oken, Goethe, Treviranus and Geoffroy St. Hilaire. I shall have occasion later to speak of these men in considering the development of the evolutionary idea, as their philosophical speculations were largely concerned with the transmutation of species. But great as was the service rendered by them and others in establishing a broader, philosophical spirit and in attempting to discover underlying general principles of zoölogy, their speculations frequently led them into serious error. Just as the pendulum had swung to one extreme with Linnaeus and his followers on the empirical side, it reached in the school of nature-philosophers the opposite limit in their uncontrolled speculations. From the time of Linnaeus, a general survey of zoölogical science shows us a continual vacillation between these two tendencies, the empirical on the one hand and the speculative on the other. Now, as opposed to the many errors of the nature-philosophers, the great French naturalist, Cuvier, brought the pendulum back to the empirical method by re-establishing, extending and developing the study of comparative anatomy, an empirical method, however, which was far sounder and more valuable than that of the former systematists. The Cuvierian Period held sway until the middle of the century when it in turn gave place to a second philosophical reaction with the beginning of the Darwinian Era.

From the time of antiquity those who concerned themselves with philosophical conceptions of nature regarded animals as constituting a linear series of increasing complexity, or a *scala naturae* as it was called, and to this conception Linnaeus' system of classification lent great weight. Linnaeus believed that the whole animal kingdom could be arranged in such a series, beginning with the simplest forms and ending with the most complex, the species falling within the genera, the genera within the orders and the orders within the classes, succeeding one another in regular linear gradation.

In the history of systematic zoölogy the only name between Linnaeus and Cuvier which need be mentioned here is that of Lamarck who, however, is chiefly distinguished as the founder of a theory of evolution. Lamarck's classification was merely an enlargement and logical development of Linnaeus', but owing to the progress which had been made during the fifty years intervening in the knowledge of animal forms, especially of the lower forms, it contained twice as many classes and ten times as many genera as were recorded by Linnaeus. To him is due the introduction of the terms invertebrate and vertebrate to indicate animals without and those with an axial supporting structure or back-bone.

In the revolt against the systematists during the latter part of the eighteenth century the study of comparative anatomy, long laid aside for species-description, had its rebirth, and there had arisen as a result of the comparisons made between the different parts of the same organism and similar parts of different organisms two great principles; namely, the Correlation of Parts and the Homology of Parts. According to the former it was recognized that an organ is not an isolated thing but that there exists in the body a mutual dependence of all its parts, certain features in one structure being always associated or correlated with certain features in another, as for example, in the teeth and in the digestive tract. The principle of correlation, first formulated by Cuvier, was soon to be carried by him to an extreme in maintaining that from a single bone or claw of an extinct animal the entire body might be reconstructed, so definite is the relation of one part to another.

Of still greater importance was the recognition of the fact that structures of different animals or plants are frequently built upon a similar plan, exhibiting thus a fundamental resemblance, even though the functions of the parts in question may be quite different. This led to the recognition that structure, not function, determines resemblance, for it was discovered that organs practically identical in form and structure may be used for totally different purposes. There consequently arose the important conception of homology and analogy of parts, and organs possessing the same plan of structure and general relations were said to be homologous, as the wing of the bird and the fore-leg of the mammal, or the lung of the higher vertebrates and the swim-bladder of the fish; and organs differing in plan of structure, though having a similar function, were regarded as being analogous, as the wing of the bird and the wing of the insect. The principle of homology, though its meaning was not understood at the time, was destined to assume the highest prominence later on when the fact had become established that structural resemblances of parts are due to a community of descent.

One of the most noteworthy of the early homologies advanced at this period is that proposed by Goethe in his "Metamorphosis of Plants," published in 1790, in which he maintained that the parts of a flower, sepals, petals, stamens and pistil, though apparently widely different, are in reality modified leaves; an homology which is still adhered to.

The vertebral theory of the skull, independently put forward by Goethe and Oken, should also be mentioned, for although it has had to be discarded, it played an important part in the development of the conception of homologies. According to the theory the skull of a vertebrate was supposed to consist of a number of closely united segments, each representing a modified vertebra, similar in all essential respects to a single vertebra of the spinal column; the skull would therefore, merely represent the consolidated anterior region of the back-bone. Later investigation of the skull of the lower vetebrates, where it consists, not of separate parts more or less firmly united, but of a continuous cartilaginous case surrounding the brain, has led to an abandonment of Goethe's and Oken's theory, but it still remains of deep historical interest.

The doctrine of homologies was much elaborated and extended by that master of comparative anatomy, Cuvier (1769–1832), who until the time of Darwin was the most commanding figure in the zoölogy of the century; and we must now direct our attention for a moment to his influence upon the development of the science.

Owing to his vast researches in comparative anatomy, of both invertebrates and vertebrates, the idea of homology of parts became deeply rooted in Cuvier's mind, and it was this principle which led him to an entirely new view of the relationships of animals, a view which may be called the Type-theory, as opposed to the *scala naturae* of Linnaeus and others. He recognized four distinct types of structure in the animal kingdom, each distinguished by a peculiar plan of structure of its own; and under each branch, or *embranchement*, he arranged the Linnaean groups. His classification as finally elaborated and published in "Le Règne Animal" in 1829 is as follows: —

First Branch. Animalia Vertebrata.
Class 1. Mammalia.
" 2. Aves.
" 3. Reptilia.
" 4. Pisces.
Second Branch. Animalia Mollusca.
Class 1. Cephalopoda.
" 2. Pteropoda.
" 3. Gastropoda.
" 4. Acephala.
" 5. Brachiopoda.
" 6. Cirrhopoda.
Third Branch. Animalia Articulata.
Class 1. Annelida.
" 2. Crustacea.
" 3. Arachnida.
" 4. Insecta.
Fourth Branch. Animalia Radiata.
Class 1. Echinodermata.
" 2. Intestinal Worms.
" 3. Acalephae.
" 4. Polypi.
" 5. Infusoria.

It may be mentioned here that the embryologist Von Baer (1792–1876) adopted Cuvier's four divisions, calling them the Vertebrate, the Massive, the Longitudinal, and the Peripheric, and believing that the same unity in plan of structure could be recognized in the development of each group.

In Cuvier's mind the identity of plan existing throughout a group is the expression of an idea of the Creator, and not only is the species a fixed and permanent reality but the type as well. He vigorously combatted the speculations of the nature-philosophers regarding the transformation or evolution of forms; while the variation of the details of structure within a single type, with the retention of .the essential plan, was to him merely evidence of the Creator's consummate skill. He was led into bitter controversy with his opponents, or those who held to the transmutability of species, the conflict reaching its climax in the famous dispute in the French Academy between Cuvier and St. Hilaire, the leader of the French nature-philosophers. This discussion took place in 1830 and lasted through several sessions, the result being that Cuvier through his greater authority and much wider knowledge of comparative anatomy completely vanquished his antagonist. The victory thus won by Cuvier, by force of arms as it were, for the immutability of species and fixity of plan in nature, completely dominated the study of zoölogy until Darwin's time, and feeble were the efforts made to dislodge it during the intervening thirty years. The last serious advocate of Cuvier's types was Louis Agassiz, who held the rare distinction of being the only naturalist of prominence to reject the doctrine of descent and who until his death remained a bitter opponent of Darwin.

Foremost among Cuvier's disciples may be mentioned Richard Owen who carefully dissected and studied many animals, both vertebrate and invertebrate, including a number of very rare forms, such as the Pearly-Nautilus and the New Zealand Apteryx. He especially concerned himself with the reconstruction of extinct vertebrates, following the Cuvierian method founded on the principle of correlation of parts. The terms homology and analogy are due to Owen, who rendered zoölogy an inestimable service by clearly and definitely distinguishing between homologous and analogous structures.

After Cuvier's death the center of zoölogical progress moved to Germany, where to a greater degree than anywhere else the study of the minute structure of animals and their development by the aid of the compound microscope had given the science an immense impetus.

Contemporaneous with Cuvier was Johannes Müller (1801–1858), the greatest of all investigators of animal structure, whose reputation for rapid, exhaustive and accurate observation has never been surpassed. Possessing a remarkable comprehensiveness of view and unusual skill in dissection, he achieved brilliant results not only in the field of anatomy, but also in that of embryology and physiology. His memoirs upon the structure of Amphioxus and Bdellostoma, two of the lower vertebrates; on the anatomy and classification of Fishes; and on the development of Echinoderms, are some of his most important researches, and still stand among the marvels of zoölogical investigation.

It is impossible to even enumerate the host of workers of this period who advanced the science in rapid strides, adding far-reaching discoveries in anatomy and embryology and correction of former errors. Reference has already been made to the able embryologist Karl Von Baer, the discoverer of the mammalian egg, who may be said to have really founded the study of embryology. Thompson in England removed the Cirripedia from the group of Mollusca where Cuvier had retained them, and from a study of their development placed them, where they properly belong, with the Crustacea. Siebold established the group Protozoa in its modern signification, separating it from Cuvier's Radiata; and a decade later (1848), Leuckart finally did away with the Radiata altogether by dividing the remainder into two groups; namely, the Coelenterata (polyps, medusae, etc.), and the Echinodermata (star-fishes, sea-urchins and related forms); two distinct branches which only very superficially resemble each other. Siebold further abolished Cuvier's Articulata, transferring the Annelida to the Vermes or worm-group, and proposing the term Arthropoda for the rest, including Crustacea, Insects, Myriapods and Spiders.

We now arrive at the Darwinian Era, or the period when the doctrine of organic evolution became established. Although I shall speak of the development of evolutionary views in another place, it will be well here to refer to the profound influence which the acceptance of the theory of natural selection exerted upon the progress of morphology. With the rejection of the old and erroneous conception of species and with the establishment of the doctrine of genetic descent of all living things, at once a natural classification of animals became possible, a classification which should express, not arbitrarily chosen differences and resemblances, but actual relationships. The nearness or remoteness of descent of a given form would now determine its position in the system, which would thus be an attempt to indicate the lines of descent and interrelationships of all known animals.

A flood of light burst for the first time on the mass of accumulated facts which gradually began to assume an orderly arrangement and to take their proper positions according to the general principle of organic evolution. Facts previously misinterpreted received a rational explanation, and facts which before had no significance, or which had merely been referred to the will or pleasure of a Creator, now assumed a real meaning. The breath of life as it were had been breathed into the science of zoölogy.

Evidence for the theory of descent is drawn from four great sources, namely, comparative anatomy, embryology, palaeontology and geographical distribution; and it is but natural that with the acceptance of the doctrine, which soon became practically universal among zoölogists, these four departments of zoölogical investigation should have sprung forward with giant leaps in the feverish haste of workers to gain further evidence for Darwinism. Homology had received a real explanation, for the reason why a part of one animal resembles in structure the part of another, though perhaps differing in function and external appearance, is because it has been inherited in both cases from an ancestor possessing a similar part constructed after the same fundamental pattern.

The discovery and interpretation of homologous structures, now called homogenetic structures, gave to comparative anatomy a new goal, and led to a hitherto undreamed-of expansion of the study.

Before Darwin's work the embryologist Von Baer had announced his discovery that the higher animals pass through, in their individual development, stages which correspond more or less closely with the adult grade of organization of lower forms; but although the discoverer of a great law, Von Baer had no notion of its important meaning, nor had any of his contemporaries, except that many regarded it merely as illustrating the general harmony of plan in creation. Fritz Müller, one of the most ardent of Darwin's early supporters, from his observations upon the development and life history of Crustacea, was the first to point out its significance for the evolutionary theory. It is now known as the Law of Recapitulation, or the Biogenetic Law as Haeckel called it, and in general it states the now well-known fact that "an animal in its growth from the egg to the adult condition tends to pass through a series of stages which are recapitulative of the stages through which its ancestry has passed in the historical development of the species from a primitive form; or more shortly, that the development of the individual (ontogeny) is an epitome of the development of the race (phylogeny)." As an animal in its development is believed to retrace, as it were, its line of descent, it can be readily seen what an impetus the formulation of this principle gave to the study of embryology, for there could be found the actual record, often obscured, modified and blurred it is true, but, nevertheless, a more or less complete record of its ancestral history. For many years afterwards the greatest attention was directed to the working out of phylogenies or ancestral histories through the study of comparative anatomy and embryology; and as a result of these researches, carried on by zoölogists over the entire world, the growth of our knowledge in these subjects was stupendous. As every epoch-making discovery by a master-mind has set the trend of investigation for a long period following, so the study of phylogeny dominated zoölogy from Darwin's time down to the beginning of the last decade. Science does not develop logically, but follows the paths of least resistance; and with the almost endless wealth of material at hand, made especially easy of access by the establishment of many marine laboratories along the coasts of Europe and America, and augmented by the rich collections brought back by scientific expeditions, it is not surprising that so fascinating a study should have absorbed zoölogists for a long time. During the past ten years other problems have occupied the attention of investigators to a greater degree, and phylogenetic researches have been going out of fashion.

It would be an impossible task to speak here of the countless discoveries made in the field of comparative anatomy and embryology under the inspiration of the doctrine of descent, for our modern knowledge in these branches, which has largely been the outcome of researches carried on during this period, has attained enormous proportions. Our present system of classification, which attempts to express the probabilities of genealogical relationships, embodies the results of our anatomical and embryological knowledge of to-day. Every group of animals has been most carefully studied, its anatomy and development accurately described and pictured, and although gaps exist here and there, the amount of information which we now possess was undreamed of even in Darwin's time. Old groups have been broken up and several classes made of them, as for example, the Mollusca, which has been forced to surrender the Brachiopoda, the Bryozoa and the Tunicata, as more careful anatomical and embryological study has brought to light their special affinities. The group of Vermes which so long remained the dumping ground for all forms whose relationships were obscure has in the latest proposed classification been discarded altogether and it is now represented by a number of separate branches. We now recognize twelve *phyla*, or main subdivisions of the animal kingdom, including fifty-one classes and several appendices, or groups whose affinities are doubtful. It is probable, however, that any classification will receive only a temporary acceptance, and will for a long time to come be subject to much remodeling and revision, as discoveries are made which necessitate change.

The study of palaeontology, a science which could hardly be said to have been in existence a century ago, received the same impetus from the doctrine of descent as did comparative anatomy and embryology, and it has undergone a marvelous development in our epoch. If the present fauna is the last link in the long series of animal forms which have succeeded one another by slow and gradual substitution of species, it is from an examination of the fossiliferous remains that we should find the prima facie evidence of evolution. Cuvier and his disciples, it is true, had already studied the fossils of the Paris basin with rich results, but it was not until after Darwin that the science entered upon its modern development. Considering the difficulties that beset any palaeontological investigation and the fact that only a few spots in the earth's crust have been scratched for fossiliferous remains, the achievements have been remarkable. Huxley in England and the American school of palaeontologists, notably Cope, Marsh, Osborn and Scott, have brought to light a wealth of material, the western plains of the United States alone yielding a world of extinct animal forms. The phylogenies of many animals have been discovered with greater or less completeness, as for example, that of the horse, and the proofs of organic evolution which palaeontology has furnished have even surpassed expectation.

II. EVOLUTION.

Let us now turn to a consideration of the development of evolutionary doctrines as applied to organic nature.

The essence of the idea of the gradual development of organisms can be traced back to the Greeks, for in the earliest Ionians, Thales and Anaximander, more than six hundred years before Christ, we find the first premonition of evolution. Later, in Heraclitus and Empedocles who set forth the doctrine of the gradually increasing perfection of organisms, the idea became somewhat less vague, the latter even dimly foreshadowing the theory of the "Survival of the Fittest." And still later we find in Aristotle very clearly brought forth the principle of adaptation or fitness of certain structures to certain ends; but he believed that the succession of forms in evolution was due to the action of an internal perfecting principle originally implanted by the Divine Intelligence. During the sixteenth and seventeenth centuries more or less direct contributions were made to the foundations of modern evolution by the philosophers Bacon, Descartes, Leibnitz, Kant and others. But it is to the great naturalists or nature-philosophers of the latter half of the eighteenth century and the first half of the nineteenth that we must look for the definite formulation of evolutionary theories, to Buffon, Erasmus Darwin, Lamarck, Goethe, Treviranus and Geoffroy St. Hilaire. Although each of these naturalists, especially Goethe, clearly recognized the evolutionary principle as opposed to the doctrine of special creation, Lamarck alone proposed a definite system by setting forth certain factors to account for adaptations and the origin of species, and it is to his theory that we must confine our attention in this place in speaking of pre-Darwinian evolutionists. The complete expression of his theory appeared in his "Philosophie Zoölogique" in 1809.

Lamarck taught that first organisms of the simplest structure arose through spontaneous generation, and that from these there have been developed in the course of a vast period of time, through gradual change, all of the present species of animals and plants without any break in the continuity. The last and highest member of the series is man who has therefore had a common origin with the lower forms. The causes which have brought about these changes, or in other words the factors of evolution, according to Lamarck, are the inherited effects of use and disuse, the action of the environment, and the influence of conscious effort or willing on the part of the animal. The giraffe for example, has acquired a long neck because he has been compelled to stretch his neck in order to browse upon the leaves of trees, living as he does in regions of sparse vegetation; and again, the blind fish living in dark caves has lost its eye-sight through disuse of its organs of vision. Lamarck regarded the influence of environment as of secondary importance and as acting only indirectly upon animals by changing the conditions for the use of organs.

In maintaining a continuity of development for all organic forms Lamarck rejected the cataclysm theory of Cuvier by which the latter accounted for the successive series of animals and plants found in the fossiliferous rocks of each geological age. According to the doctrine of cataclysms a great revolution or convulsion of nature had brought to an end each period of the earth's history, with the destruction of all life, and upon the newly formed earth a fresh and newly created world of fixed species had been placed by the Creator, only to be wiped out of existence in its turn by the next cataclysm. Lamarck's spirited writings remained almost unnoticed by his contemporaries, and met with only contempt from Cuvier who spoke of each edition of his works as a "*nouvelle folie.*"

In 1830, a year after Lamarck's death, Cuvier won his famous victory over St. Hilaire, with the result as already mentioned, that the doctrine of the mutability of species remained buried until it was revived nearly thirty years later by Darwin and Wallace. In the same year, however, Cuvier's theory of cataclysms received its death blow from the geologist Lyell who in his epoch-making work, the "Principles of Geology," completely set aside the doctrine of convulsions and explained the past changes of the earth's surface as due, not to violent intermittent revolutions, but to the constant action of physical agents which are still in operation, as for example, the erosive action of water. Only gradually then has one period of the earth's history passed into the next and without any break in the continuity. For these changes to have taken place vast periods of time must have been necessary; and it is with this deduction from Lyell's work that the biologist is especially concerned, as it allows of the requisite length of time for the changes to have taken place in the organic world in the gradual evolution of species. And from this point of view Lyell furnished Darwin with a strong support for his theory.

Darwin. — So complete had been the overthrow of the transmutation-theory that the special-creation view of species rested quietly for over a quarter of a century without receiving a serious attack. Evolutionary doctrine had remained obscured for so long that Darwin's "Origin of Species" came upon the stage with startling abruptness; and hence the Darwinian Era is sharply marked off from the preceding period.

In the brief limits of this lecture it is impossible to give to Darwin his true relative position or to adequately picture his towering pre-eminence over all of his predecessors.

During his long voyage as naturalist on the war-ship "Beagle," detailed by the British Admiralty from 1831 to 1836 for nautical researches, Darwin had been deeply impressed by the striking character of island faunas, especially of the Galapagos Islands, and by the remarkable distribution of Edentates in South America. Although on the voyage he was a believer in special-creation, the peculiarities of distribution which he had observed caused him to think much on the subject of species, and he says he was haunted by the problem of mutability. On his return he began to systematically collect from every available source facts concerning variations of animals and plants under domestication and in a state of nature, and to carefully search the literature of the subject. "In October, 1838," he says, "I happened to read for amusement Malthus on Population, and being well prepared to appreciate the struggle for existence which everywhere goes on, from long continued observation of habits of animals and plants, it at once struck me that under these circumstances favorable variations would tend to be preserved and unfavorable ones destroyed. The result of this would be the formation of new species. Here, then, I had at last got a theory by which to work." So cautious was he, however, that he published nothing for many years afterwards and it was not until 1842 that he even wrote an outline of his view for his own satisfaction; and this brief abstract he enlarged two years later. At that time he wrote his friend Hooker, "I have been ever since my return, engaged in a very presumptuous work, and I know no one individual who would not say a very foolish one. I was so struck with the distribution of the Galapagos organisms and with the character of the American fossil mammifers that I determined to collect blindly every sort of fact which could bear in any way on what are species. At last gleams of light have come, and I am almost convinced (quite contrary to the opinion that I started with) that species are not (it is like confessing a murder) immutable. Heaven forfend me from Lamarck nonsense of a 'tendency to progression,' 'adaptations from the slow willing of animals,' etc! But the conclusions I am led to are not widely different from his; though the means of change are wholly so." This quotation well indicates the general attitude of the time toward the immutability of species, to doubt which was high crime.

Darwin's reluctance to publish his theory until he had collected a vast amount of evidence came near costing him his right to priority. In 1858, twenty years after the idea of Natural Selection had occurred to him, during which time he had devoted all of his energy to gathering every possible fact and observation in support of his doctrine, he received an essay from his friend, the naturalist-traveler, Alfred Russel Wallace, who was then in the Malay archipelago. Wallace's paper contained an outline of a theory of Natural Selection which, though differing in certain points, was essentially the same as that which Darwin had long before arrived at. Under persuasion of his friends Hooker and Lyell, Darwin consented to give publicity to his theory and on June 30, 1858, a modest abstract, consisting of his earlier notes, together with Wallace's essay, appeared in print in the Journal of the Linnean Society. In the year following (1859) was published the most important of his writings, "The Origin of Species by Means of Natural Selection, or the Preservation of Favored Races in the Struggle for Life," and in rapid succession afterwards the complete series of his works, representing the results of many years of labor. Those which bear more directly upon the theory of descent are "The Variation of Animals and Plants under Domestication," and "The Descent of Man," the latter applying the theory of Natural Selection to man.

So completely had evolutionary theories been forgotten that Darwin's work was almost universally regarded as something entirely new, and at once it provoked the most violent opposition, to some extent from scientific men, but mainly from the clergy. Only a few men of science placed themselves at the beginning on the side of Darwin, and for some years a fierce battle was waged between the advocates and opponents of Natural Selection. Darwin took little part in these controversies himself, and it was largely due to the spirited efforts of a handful of loyal supporters, notably of Huxley in England and Haeckel in Germany, that the brilliant victory for the descent-theory was won. Although ideas of organic evolution had been expressed at intervals from the time of the Greeks, and in a few instances a cause of the transmutation had been offered, as in Lamarck's system, Darwin was the first to propose a reasonable explanation of the origin of species based upon observed fact. No scientific work of the century has attracted so much attention, not only in the zoölogical, but in the entire educated world; and at the present time our whole scientific thought is so thoroughly permeated with the idea of the descent-theory, that there is no department of knowledge which has not felt its far-reaching influence.

So familiar is the theory of Natural Selection to every one that the briefest outline will suffice. The over-production of individuals leads to a fierce struggle for existence among all living things, a struggle which is both active and passive, occurring not only between organisms but between the organism and its environment, a struggle which is to result either in the destruction of the individual or its survival. Those individuals survive which can, and it is the fittest, or those which are best suited to withstand the ceaseless life-struggle, that will constitute the favored. Upon Darwin's theory the origin of species is accounted for by the hereditary transmission of "fortuitous" congenital variations which are useful to the organism by giving it an advantage in the struggle for existence and thus determining whether the organism is to survive to produce offspring or to perish without leaving offspring. In order that the character should be selected, it must be useful, must be at some time a life-preserving character, and the fundamental principle underlying the process of Natural Selection is that of utility. It is a matter of common observation that no two individual animals or plants of the same species, even those derived from the same parents, are precisely alike, but show countless differences, "variations" as Darwin called them. It has been thoroughly established by observation that all parts of the organism are subject to variation, and furthermore, that any variation in the parent tends to be transmitted to the offspring. Should any of the innumerable variations of the body be of utility to the possessor in the struggle for existence, that is, should it be a determining factor in deciding whether the possessor is to survive or perish, it will be *naturally* selected, and the offspring will tend to receive the same advantage. In this way Darwin explained the origin of adaptations, those exquisite adjustments of the organism to its environment which before his work seemed so purposeful that a supernatural Intelligence was thought necessary to account for them. But Darwin showed that many, if not all, adaptations could be satisfactorily explained by the inheritance of those accidental or fortuitous variations which have been selected naturally from among innumerable indifferent variations by reason of their life-preserving value in the struggle for existence. By a slow and gradual process, useful variations once established would be perfected by further transmission of additional improvements along the same lines, until adaptations, as we see them now, in all their intricate complexity and perfect adjustment would result.

Early in the history of the doctrine the objection was urged, and for a long time strongly pressed, that until a variation had at least reached a considerable degree of development it could not be useful and hence could not determine survival; and moreover, that a single favorable variation would soon be lost by the swamping effect of cross-breeding. As an answer to this argument, it has been shown since Darwin's time (and this has been one of the most important of the later additions to the theory) that it is not necessary for a variation to be of profound significance at first, but that a gradual advance may take place by raising the general average of each generation even by a slight amount. It has been clearly shown that variations occur around a mean, and that with regard to any particular character animals or plants arrange themselves mainly into groups — those above and those below the average.

However slight a given variation might be above the mean, in times of stress the survivors would contain a relatively larger number of individuals possessing that advantage, and this being repeated at subsequent generations, natural selection would establish adaptations by thus gradually raising the general average. The advance would therefore be, not by isolated spurts of individual variations, although it is possible that this might take place in certain cases, but an advance of the species as a whole. And furthermore, as it is largely those individuals falling below the mean which are exterminated, the survivors would have to mate with each other, and there would be no opportunity for the new character to be eliminated by cross-breading.

The necessity of variations occurring in definite, beneficial lines, as opposed to indiscriminate variation, in order to produce adaptations, that is, the necessity of their being determinate, has for a long time appealed with force to the minds of some. If variations are determinate, if there is some underlying cause which calls forth the variation when needed and directs its development, then, it is argued, Natural Selection would not be the cause of evolution, and the real problem of evolution would be the discovery of the cause of the determinate variation. There has arisen a school of biologists who, working from this standpoint, have attempted to identify this cause with the old Lamarckian factors but with modifications necessitated by the advance of zoölogical knowledge. The all-sufficiency of Natural Selection as the cause of evolution, is denied by these Neo-Lamarckians who maintain that use and disuse and the action of the environment produce and determine variations, directing them along beneficial lines; and moreover, that the effects of these factors upon the individual are transmitted. They assign to Natural Selection only a secondary role in contributing to the establishment and elaboration of variations after they have once been produced by use or disuse or by the action of the environment and brought into existence when needed. During the past twenty or twenty-five years the contention over Natural Selection *versus* the inheritance of "acquired characters" has proceeded with considerable earnestness, and has attracted much interest from the educated world at large, owing to the practical importance of the question for sociological and educational problems.

In the latter part of his life, Darwin admitted the possibility of the Lamarckian factors, though strenuously denying them in his earlier writings. Herbert Spencer and Romanes in England, Haeckel in Germany and the American school of palaeontologists have been the strongest advocates of Neo-Lamarckianism, while the all-sufficiency of Natural Selection has been stoutly upheld by Wallace, but above all by Weismann and his followers. Although Natural Selection stands upon a firmer footing than perhaps it has ever stood, the general attitude among biologists is that, although the Neo-Lamarckians have not made good their claim and have advanced no convincing experimental proof of the inheritance of "acquired characters," it is still possible that these factors, or yet some undiscovered ones, may have operated with Natural Selection to bring about adaptations and the origin of species. The discussion has been largely of an *a priori* nature and little or no advance had been made toward a settlement; and the majority of biologists, I think, are willing to look upon it as an open question for the future to decide, if it is ever to be decided. During the past few years, however, a serious attempt has been begun to carefully study the origin of variations, without any bias towards one theory or another, in the hope that the question of whether variations are determinate or not may be settled. Already some valuable results have come from this work, done almost entirely in this country, and it has given promise of becoming a most important branch of zoölogical investigation.

III. THE CELL DOCTRINE.

Here we must leave the history of organic evolution and look for a moment at the advance made in another great department of zoölogical science, a development which has taken place almost independently of evolutionary views and entirely in the nineteenth century. I refer to the development of the so-called cell-theory which has created the science of cytology almost within the past twenty-five years. This remarkable growth which has taken place in our knowledge of the structure and activities of cells has been immensely aided, in fact made possible, by the great improvement within recent years of microscopical lenses, by the invention of accurate microtomes and by the perfection of methods of hardening, staining, imbedding and serial section-cutting. It has thus become possible in cytological research to preserve, with little distortion, the most delicate of cell-structures, to bring into view, by means of differentiating stains, objects which would otherwise be invisible, and to examine them, in sections of only one thousandth of a millimeter in thickness if need be, under remarkably high powers of magnification.

In all the higher forms of animal and plant life the body consists of innumerable structural units, termed cells, out of which, directly or indirectly, every part is constructed; and the view that all organisms are composed of these elementary minute particles is known as the cell-theory which is rightly considered to be one of the most important generalizations in the history of modern biology.

The essential substance composing cells is living matter or protoplasm which was termed by Huxley the "physical basis of life" and which is now universally regarded as the seat of all manifestations of life. In the lowest organisms the body consists of a single cell in which all of the vital functions are performed: in the higher forms, however, the body is made up of a multitude of cells and is in a certain sense to be compared with a colony or aggregate of many unicellular forms which exhibit a division of labor among themselves, some being specially modified in structure for the performance of one function, others modified in a different direction for another function. And as the functions of the organism as a whole are but the result of the activities of the individual cells, we therefore recognize the cell, not only as the unit of structure, but as the unit of function as well. "Consideration of the individual functions of the body urges us constantly toward the cell. The problem of the motion of the heart and of muscular contraction resides in the muscle-cell; that of secretion in the gland-cell; that of food-reception and resorption in the epithelium-cell and the white blood-cell; that of the regulation of all bodily activities in the ganglion-cell. * * * If, then, physiology considers its task to be the investigation of vital phenomena, it must investigate them in the place where they have their seat, that is, in the cell." *

Ever since the formulation of the cell-theory the fact has become more and more generally recognized that the solution of all ultimate problems of biology is to be found in cell-investigation. Already the doctrine has contributed to the science many of its most important generalizations. "It was the cell-theory that first brought the structure of plants and animals under one point of view by revealing their common plan of organization. It was through the cell-theory that Kölliker and Remak opened the way to an understanding of the nature of embryological development, and the law of genetic continuity lying at the basis of inheritance. It was the cell-theory again which, in the hands of Virchow and Max Schultze, inaugurated a new era in the history of physiology and pathology, by showing that all the various functions of the body, in health and in disease, are but the outward expression of cell-activities. And at a still later day it was through the cell-theory that Hertwig, Fol, Van Beneden and Stragburger solved the long-standing riddle of the fertilization of the egg, and the mechanism of hereditary transmission. No other biological generalization, save only the theory of organic evolution, has brought so many apparently diverse phenomena under a common point of view or has accomplished more for the unification of knowledge. The cell-theory must, therefore, be placed beside the evolution-theory as one of the foundation stones of modern biology." †

As early as the seventeenth century Hooke, Malpighi and Grew had discovered in plant bodies, by the aid of low magnifying glasses, small spaces, surrounded by firm walls and filled with fluid, to which Hooke first applied the word cell. The discovery attracted little or no attention and it was not until nearly two centuries later that the cell was re-discovered.

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* Verworn, General Physiology, p. 48. 1899.

† Wilson, The Cell in Development and Inheritance, p. 1. 1898.

In 1833 the English botanist, Robert Brown, saw in certain plant structures that each cell contained a small circular spot which he called the nucleus. Five years later, in 1838, Schleiden proposed the generalization that a nucleus was an universal elementary organ in plant bodies, and in 1839 the doctrine was extended by Schwann to animal bodies. The theory is hence commonly known as the Schleiden and Schwann Cell-theory.

At first the wall or membrane of the cell was considered to be the most important part of the vesicle, while the substance contained within the wall, to which Von Mohl gave the name protoplasm in 1846, was either overlooked or regarded as a waste-product. Through a series of researches, mainly by Bergmann, Kölliker, Bischoff, Cohn, de Bary and Schultze, it was definitely proven that the cell-contents, not its walls, is the seat of the vital functions, by showing that some cells, as the white blood-cells, are merely naked masses of protoplasm. It was then further demonstrated that the presence of a nucleus was practically universal, and the cell came to be recognized as a "mass of protoplasm containing a nucleus," a definition which is accepted to-day. The word cell is therefore a misnomer, but it has been perpetuated as an historical survival in spite of numerous attempts to supplant it.

Schleiden and Schwann believed that cells might arise in the body by a process of crystallization out of a formative substance, termed "cytoblastema." It was not until years of careful research had elapsed that it was finally settled that new cells are only produced by division of pre-existing cells, and in 1855 Virchow announced his famous aphorism, *omnis cellula e cellula*. This conclusion now rests upon an irrefragable basis.

The mechanism of division, however, was little understood at first, although it had been shown as early as 1841 by Remak and Kölliker that both the nucleus and the body of the cell divide. The division was supposed at that time to take place by simple constriction, first of the nucleus into two parts, and then of the cell-body into two, each containing one of the daughter-nuclei. It was not until 1873 that the process was shown to be of a far more complicated nature and to involve a remarkable transformation of the nucleus to which Schleicher in 1878 gave the name of karyokinesis. In certain cases, however, the simpler method of division exists, which is now recognized as direct division and contrasted with the indirect method of karyokinesis. The indirect process is an intricate device for the purpose of dividing and distributing to each of the resulting two cells equal portions of a substance contained in the nucleus, termed chromatin, which we have many reasons for indentifying as the essential constituent of the cell, controlling its activity and determining its specific nature. In indirect nuclear division, therefore, the result is attained that precisely equivalent portions of the chromatin are passed into the daughter-cells which thus receive the same specific constitution as possessed by the parent-cell.

Not only do the cells of the body arise in this manner by division of pre-existing cells, but it has been shown by the painstaking labors of a host of investigators that all the cells can be traced back to the fertilized egg-cell which by a successive series of divisions ultimately gives rise to the vast multitude of cells composing the body of the adult. This process has now been followed with great accuracy in a large number of cases, both animals and plants, and the genetic continuity of all cells of the body has been thereby thoroughly established. Nor does the process of cell-division start with the cleavage of the egg, for the link between successive generations has been shown to consist in the fact that the egg-cell and the sperm-cell arise in the body of the parent by division of pre-existing cells and are therefore directly derived from an egg-cell of the preceding generation. The old Greek doctrine of equivocal or spontaneous generation has long since been discarded, and we now know that living things constitute an uninterrupted series from generation to generation. Although the body of the individual dies, the germ-cells live on, embodying the sum-total of the race behind them and giving to the generation arising from them the expression of this inheritance.

The spermatozoön discovered by Lüdwig Hamm, a pupil of Leeuwenhoek, in 1677, and first regarded as a parasitic animalcule living in the sperm or seminal fluid of the male (hence the name spermatozoön) was in 1831 proven by Kölliker to arise directly from cells of the testis, and somewhat later its precise cellular nature was demonstrated. The spermatozoön, like the egg, is therefore a true cell, though considerably modified for its special function.

A most important step for the correct understanding of physical inheritance was next taken when Oscar Hertwig in 1875 showed that fertilization is accomplished by the union of the nucleus of one spermatozoön, which penetrates the egg, with the nucleus of the egg. During the past twenty-five years the exact details of this process have been made known through the brilliant researches of later cytologists. In fertilization we now know that the male and female nucleus contribute to the formation of the nucleus of the fertilized egg exactly equivalent amounts of chromatin which, during cleavage, is therefore distributed equally to the daughter-cells arising at each division. The marvelous result is that the determining constituent, or chromatin, of every cell of the body is derived half from one parent and half from the other. In this fact rests the physical basis of inheritance, an inheritance which is therefore twofold and transmits to the offspring the characteristic organization of both parents. Within recent years we have witnessed the establishment of the all-important fact that chromatin is identical with the germ-plasm, the substance which contains the sum-total of the species and which, when detached from the parent body, under the proper conditions gives rise to the body of the child. The problem of heredity, therefore, has become a cell-problem, and its solution lies in a correct understanding of the cell-phenomena involved.

In the eighteenth century and early part of the nineteenth, ideas concerning the sexual products and their relation to the adult organism were vague and fanciful. The ablest anatomists and physiologists held that eggs agree in their structure in every particular with the adult organism, and therefore that they possess from the beginning the same organs arranged in precisely the same manner and bearing the same relation to each other, with the only difference that they are of extraordinarily small size in the egg. The entire organism was therefore held to be preformed in every particular in the egg, but in miniature. The germ was likened to the plant bud which contains all the parts of the future flower, petals, stamens, etc., and just as the bud gradually increases in size and suddenly expands into the flower, so also in the development of animals it was believed that the already present but minute and transparent parts of the animal germ grow, expand and become visible. This doctrine was called the theory of Evolution, or Unfolding, but a later and better name was the theory of Preformation. The essence of the theory is that at no time in development is anything formed anew, but that every part of the organism is preformed in its completeness and present from the beginning in the germ. "There is no such thing as becoming" (or coming into being), says Haller, one of the great upholders of early preformation, "no part in the animal body was formed before another; all were created at the same time." It logically followed, and indeed was formulated by Bonnet and others, that in every germ the germs of all subsequent offspring must be included, since living things are developed from one another uninterruptedly; this was called the Einschachtelungslehre, or the theory of *emboîtement*, and its adherents actually attempted to estimate the number of human germs which must have been present in the ovary of Eve, accordingly reaching the number 200,000 millions.

But difficulty arose in the ranks of the preformationists upon the discovery of the spermatozoön, and the question soon came to be fervently discussed whether the egg or the seminal filament was the preformed germ. Some, the Ovists, declared in favor of the egg, others, the Animalculists, championed the spermatozoön, the latter imagining that with the aid of their magnifying glasses they could see in the human spermatozoön the head, arms and legs of the man, and regarding the egg merely as a nutritive soil in which the growth of the spermatozoön takes place.

In 1759, however, Caspar Friedrich Wolff opposed the preformation-theory and maintained that "at the beginning the germ is nothing else than an unorganized material, eliminated from the sexual organs of the parent, which gradually becomes organized, but only during the process of development in consequence of fertilization." According to Wolff therefore the organs of the body are only gradually differentiated during development out of an originally undifferentiated germinal material. For many years his theory was buried in obscurity, but it was later brought to light and to-day he is accepted as the founder of the theory of epigenesis, the rival of Weismann's doctrine of preformation. In recent times with the development of the cell-theory, with a closer insight into the nature of cell-processes, and especially with the advance of our knowledge of the finer structure of the germ-cells, much in Wolff's doctrine of unorganized germinal matter has had to be discarded, but the essential conception of his theory of development has laid the foundation of modern epigenesis.

The two opposing points of view, preformation and epigenesis, around which the earlier discussion took place, strange to say, furnish the modern contention in discussions regarding the nature of development. Our more accurate instruments and more refined methods, it is true, have forced the abandonment of what was crude and grotesque in the earlier views, but the fundamental conception of each theory is the same and has been actively fought over in the last decade. Although in recent preformation-theories it is not maintained that the embryo is actually preformed in the germ in its complete and final organization, the view has been strongly advocated that the organism is predetermined in the sense that different regions of the germ contain different substances which are destined to form definite parts of the embryo; in other words, that the head, for example, is formed in development from a certain definite and predetermined portion of the germinal substance and from that alone.

Time will permit of but the merest reference to the final product of these opposing theories, namely the modern Preformation Doctrine, first formulated by Wilhelm Roux in 1883, but greatly elaborated and extended by Weismann, and modern Epigenesis, whose chief exponent has been Oscar Hertwig.

Weismann has postulated for the germ-plasm a complicated architectural structure which is a definite and predetermined arrangement of elementary vital units, each of which is destined to form a particular and definite part of the body. These units are distributed during the course of cell-divisions occurring in embryological development to their respective positions in the body where they control and determine the development of those special structures only which they are destined to form. And, furthermore, he maintains that a certain undifferentiated portion of the germ-plasm is passed into the germ-cells where in the next generation it becomes in turn disintegrated in forming the body of the offspring. He thus postulates an uninterrupted continuity for the germ-plasm which bridges across the gap from one generation to the next, as contrasted with the perishable body of the organism which is destroyed at the death of each individual.

Much of Weismann's doctrine has been recently shown to be without a foundation of fact, and great as has been its influence in stimulating the progress of this phase of zoölogical investigation, the theory has been largely given up for an epigenetic view of organic development.

According to epigenesis the organism is not preformed in the germ in all its final complexity of structure, but many of the characters of the adult arise secondarily during development, being the result of the interaction of internal and external forces and coming into existence only after many cells have been formed by division and grouped in different ways both in relation to each other and to their environment.

As to the ultimate problem of heredity and development, zoölogy is still completely in ignorance. Weismannism throws it one step farther back and transfers it from the visible to the invisible, without supplying a real explanation. Epigenesis has no answer at all, not even a formal one, to the fundamental questions of heredity and development. What we want to know is this: What is the peculiar organization of the germ-plasm upon which we are driven to believe inheritance depends, and what is the power that controls the intricate phenomena of development and directs them to a definite and foreseen end? In some way the nature of the individual cell determines how it is going to react to external forces and stimuli, and how it is going to be combined in a definite manner with other cells. Two fertilized egg-cells, subjected to precisely the same external conditions, react in utterly different ways. A hen's egg and a duck's egg, lying side by side in the same incubator, or under the same hen, give rise one to a fowl and the other to a duck. The difference must be attributed to a difference in the nature of the cell itself, and whether we shall ever understand what lies behind this difference remains for the future to decide. We can, however, guard against the delusion that we have an explanation where none exists. Yet so brilliant have been the achievements within the past few years in the fields of cytological and experimental research, that we can set no limit on the possible advance in our knowledge of inheritance and development.

IV. EXPERIMENTAL MORPHOLOGY.

Finally, this outline of the advance of zoölogy in the century would be incomplete without a reference to a very recent development of the science which has been brought about by the application of the experimental method to the investigation of fundamental problems of heredity, development and growth. In the field of embryological development, the investigation has been pushed with the greatest enthusiasm, and by subjecting the egg to entirely new conditions, which can be altered and controlled by experiment, illuminating and far-reaching results have been obtained. Not only has the egg been thus experimentally studied, but the same method has been applied to all developmental stages from the time of fertilization onward. It has been entirely through work of this nature that we have arrived at an epigenetic conception of development.

Again, much attention has been directed to the study of the regeneration or replacement of lost parts by growth in animals and plants, an investigation which obviously lends itself well to the experimental method, in the hope of discovering the causes underlying this remarkable power of living things. Although the study is only in its first stages of development, it is to be hoped that by its further pursuance much light will be thrown upon fundamental vital processes.

The tendency to-day, especially among the younger men, is to depart from the older lines of investigation and to strike at the solution of the activities of living things by the use of the experimental method, to reduce, in so far as possible, vital activities to known laws of physics and chemistry, and to thus attack the fundamental problems of life. A glance at the biological journals of the day will convince one of the absorbing interest which is displayed on every hand in experimental work, and the number of their pages which are being devoted to these researches is sufficient evidence of the present tendency. Such problems as the effect of external agencies, temperature, light, gravity, electricity, chemical stimuli, etc., upon protoplasm in all its forms and conditions are being eagerly investigated. One of the most recent results obtained from investigations of this nature is the startling discovery a short time ago that unfertilized eggs of the sea-urchin, when subjected for a time to the action of certain inorganic salts in definite solutions, develop parthenogenetically into normal larvae. Where this discovery will lead us, to what degree it will cause us to reconstruct our conceptions of fertilization and hereditary transmission, it is too early to say, but it is probable that it will necessitate a considerable remodeling of some of our present ideas.

The whole subject of experimental morphology is too young to surmise what results it will yield in the future, but it undoubtedly gives promise of brilliant achievements. It is a field of research which is attracting many of our ablest biologists who feel little confidence of progress along the lines of speculation and discussion which have so largely occupied zoölogists and botanists since Darwin's time.

It is not too much to hope, however, that in this new departure of experimental research we may be led to the discovery of some of the unknown forces which confront us in the last analysis of all vital phenomena.

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PHYSICS DURING THE LAST CENTURY.*

FRANCIS E. NIPHER.

The study of physical science had its origin among people who had been accustomed to reach most of the results which seemed to them of value, by processes of a purely mental character. After the result had been attained it was considered important that it should be accepted by others. It was regarded as a duty for every man to convert others to his philosophy. It was considered of importance if some record of a predecessor could be found and quoted, showing that the new result was in line with precedents. It is difficult for us in this day to realize the endless quarreling, and irrelevant or senseless debating which attended the early advances in every branch of science. It is one of the greatest advances in science that we no longer consider it of importance that our thinking should square itself with the ideas of those who have preceded us in a former age, and who perhaps did not and could not think seriously about the matter at all. It is certainly an advance of a very fundamental and far-reaching character, that our explanation of the working of a pump does not involve the proposition that "Nature abhors a vacuum." It is hard for us to understand how men of a former time could have felt any mental stimulation in the doctrine that the number of planets could not exceed the number of openings in the head of a man, or that anything could be proved by an astonishing illustration of something else.

In the century which preceded the last there were men who began to have what we should call a sense of logical connection in physical reasoning. In the preface to Rohault's Natural Philosophy, the English edition of which appeared in 1729, are some keen and discriminating comments upon what

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was then considered as logical and sufficient among the schoolmen. The writer says: —

If you ask a ploughman why it is that the loadstone attracts iron, he will tell you that he does not know. If you ask of the schoolman he will tell you that it is by reason of an occult property which the loadstone possesses. Now this, as the writer goes on to say, is to say the same that the ploughman said, but in language which might delude the ignorant into the belief that the thing has been explained.

During the last century and particularly during the latter half, the opposition to the intellectual freedom which the man of science demands, has practically ceased. The so-called scientific method has found its way into the intellectual workshops of all who make pretense to scholarly attainment. In its promise of future good this is the great achievement of the past century.

When we come to sum up the results of scientific study in physics, it is impossible to do more than to briefly allude to the broader outlines. There is one result which is of central importance. It is the doctrine of the "conservation of energy." The student of our day who reads the earlier papers of Mayer, Helmholtz, Grove, and others, written between 1840 and 1850, will find much to bewilder him. The notation and phrase-coining necessary to state the problem which they were solving, had not yet been effected. New ideas were being brought into focus and there was a new quantity to be dealt with, and measured, but it had no name. They called it "force" but Mayer clearly pointed out in his paper on the mechanical equivalent of heat in 1851 that this was a different meaning from Newton's.

Speaking of the word *Kraft*, he says: —

"I. On the one hand it denotes every push or pull, every effort of an inert body to change its state of rest or motion."

In his day they sometimes called this "mere force" or "dead force."

"II. On the other hand the product of the pressure into the space through which it acts, and again the product — or half product — of the mass into the square of the velocity is named force."

This they usually called "living force," a name which was later for a time restricted to the quantity MV^2.

He, however, goes on to say that "force and the product of force into the effective space are magnitudes too thoroughly unlike to be by an possibility combined into a generic conception," and he recommends that the name force be restricted to one or the other of these meanings. Nevertheless it was not uncommon twenty years later to read in the books of that time that the unit of force was the foot-pound.

The word pressure is still misused in this way by many literary and engineering writers. It is used to denote force per unit-area, and force.

The doctrine of the Conservation of Energy grew very naturally out of the discovery that a definite quantity of heat is directly producable from a definite quantity of work. In a qualitative way the identity of heat and molecular motion had long been insisted upon. In Rohault's Natural Philosophy, before referred to, is a chapter devoted to this subject. The writer says (I, 155): —

"We observe *that two hard Bodies rubbed against one another*, do so agitate the parts of each other, as not only to burn us when we touch them, but their Motion will increase to such a Degree as to set each other on Fire. Thus in very dry Weather, the *Wheel* and the *Axle-tree* of a chariot, when it goes very quick, and in general, all sorts of Engines which are made of Matter that will burn, and which move very quick, are apt to take Fire. Nothing is more common than to see a *Wimble* grow hot in boring a Hole in a hard thick Piece of Wood. So likewise, if we *file* or *sharp* a Piece of Iron or Steel, it will grow so hot sometimes as to lose its Temper. And a *Saw*, which the Wood will not easily yield to, acquires a very notable Heat. But nothing sooner takes Fire than a small piece of *Flint* or of *Steel*, which is struck off, and put into violent Motion by striking these two against each other. Now in all these Instances, there is nothing added to these Bodies but Motion.

"All the Antients who have considered the greatest Part of these Experiments, have asserted that *Motion* is the *Principle of Heat;* which I acknowledge with them to be true; if by

Motion they mean the Motion of the *Whole Bodies*, which is the Cause of the two Bodies rubbing against each other; but if by *Motion* they mean *the Motion of their insensible Parts*, I think they have not said enough: for the *Motion* of these Parts, is *the very Heat itself* of those Bodies."

Sixty-nine years later, in 1798 appeared Count Rumford's paper in the Transactions of the Royal Society, in which he gives an account of experiments made in the boring of brass cannon at Munich while he was in the service of the Elector of Bavaria. He tested the heat capacity of the metal borings and found them the same as the cuttings made with a sharp saw where little heat was produced. He concluded that the heat obtained in the boring was not a substance, caloric, squeezed out of the borings, and concludes: —

"It is hardly necessary to add, that anything which any *insulated* body or system of bodies can continue to furnish *without limitation*, cannot possibly be a *material substance;* and it appears to me to be extremely difficult, if not quite impossible, to form any distinct idea of anything capable of being excited and communicated in those experiments, except it be MOTION."

The advance which this great man made, was in the measurement of heat quantities. He compared the quantity of heat produced by the work of a horse, in driving the drill used in boring the cannon, with that which could be realized by burning the feed which the horse would require during the interval, and also with that produced in the burning of a definite quantity of wax in candles of specified size. This comparison was made by determining the amount of water heated from freezing to boiling.

This man Benjamin Thompson, born in Woburn, Mass., 1753, was one of the great men whom this country has produced, and whom it does not know. He was in charge of an academy at Rumford, afterwards Concord, N. H., in 1770. At the outbreak of hostilities he applied for a commission in the revolutionary army, but he was accused of toryism and left the country in disgust. Later his distinguished services to the English government and people led to his being knighted. Soon after he entered the service of Bavaria, where he brought about a revolution in military tactics, in industrial education, in the manufacture of arms and ordnance, in the suppression of organized beggary, in the improvement in construction of the dwellings of the poor, in the introduction of superior breeds of horses and cattle, and in bringing into existence a public park where the grateful people afterwards erected a monument to his honor. For these great services he received many honors, among others being made a Count of the Holy Roman Empire. He chose as a title the name of his New Hampshire home, and was afterwards known as Count Rumford. He returned to England and founded the Royal Institution of England. The great service which that Institution has rendered to the science of the last century is sufficiently indicated by a mere mention of the names of the great men who have been professors there. Beginning with Thomas Young, we have Sir Humphrey Davy, Michael Faraday, John Tyndall, and in our day Lord Rayleigh and Professor Dewar.

Rumford afterwards took up his residence in France, became one of the eight foreign associates of the Academy of Sciences of Paris, and married the widow of the great chemist Lavoisier.*

Davy was brought to Rumford's attention by some ingenious experiments which he made upon heat, although at first his ideas were far from clear. He showed that cakes of ice might be melted by friction upon each other when in an atmosphere where no melting could occur when the friction ceased. This work of Rumford and Davy, supplemented by the powerful adhesion of Thomas Young, was apparently without effect for nearly half a century. But it was not without effect. The seed had been sown, and the results showed themselves in the almost simultaneous appearance of different phases of a new and comprehensive generalization, the Conservation of Energy.

In 1842, Dr. J. R. Mayer of Heilbron, a physician, published a paper in which for the first time an attempt was made to determine the height through which a body must fall, in

* In our time Rumford's biography and works, in six volumes, have been made public by Ellis.

order to heat an equal quantity of water 1°. Here for the first time we have the equivalence of heat and work clearly stated. This value was calculated from the difference between the two specific heats. And it is perhaps worthy of remark that the direct occasion which brought about this line of work, was the observation by him while in surgical practice in the island of Java, in 1840, that blood drawn from the veins of newly arrived Europeans, possessed almost without exception a surprisingly bright red color.

At about the same time Colding in Denmark, Helmholtz in Germany, Grove and Joule in England were independently working upon the same subject. The work of Joule was the direct determination of the mechanical equivalent of the heat unit, by a method of stirring water with rotating paddles, which Rumford had suggested half a century before. Rowland has in our day improved on Joule's method, and has undoubtedly made what is, for practical purposes, a final determination of the mechanical equivalent of heat. Thomson and Clausius completed the proof, that, while the total energy of the universe is constant, a continually increasing amount of this energy is becoming unavailable. Each transformation of energy results in the production of heat, which is dissipated, and so far as we can see, becomes forever unavailable. There is no way by which this heat can be pumped back into bodies of higher temperature without a greater heat loss than that which we seek to avoid. This was the final proof that perpetual motion was impossible. The heat from coal which drives a power-house engine is only a small part of that which was liberated by the combustion under the boiler. Most of this heat is wasted through the chimney, or by radiation from the furnace boiler or cylinder. In converting the mechanical energy into a current of electricity which is to be conducted to the moving car, there is a further conversion into heat in the dynamo, the conducting wires and the motor. When the car is stopped all the remaining energy, represented by the moving car, is converted into heat at the brake-shoes, and when the car comes to rest, the entire energy potential in the coal has been converted into heat, which has been dissipated into the colder space around. It is forever beyond our reach. The water which has turned the mill, may be again lifted to the hills, and may return to drive the same mill again, but the energy which thus apparently reappears, has not really done so. It is a new supply of energy furnished us in solar radiation. And this source of energy thus tremendously drawn upon will finally fail.

In 1854 Helmholtz computed the total heat resulting from the condensation of the sun and planets, from an initial condition of zero density, to their present condition. He con cluded that only about the 454th part of the original energy remains as such, and that the heat which has already been dissipated into space, would raise the temperature of a mass of water equal to that of the sun and planets, to a temperature of 28 million degrees centigrade. He pointed out that all of the operations of our universe are of a descending character. It is a great clock which is running down. Carried backward in time these newly discovered laws point to a beginning of the present order of things. All the energies expended through historic time, whether those of Nature, or those which man has drawn upon, used and wasted, were potentially present in a cold and lifeless nebula. The struggles of men to enslave their fellows, and the struggles of men to be free, the energy which drives the pen, the cannon-shot and the mill, were all expressions of portions of the initial energy of this infinitely diffused gaseous mass, which we now in its present condition call the solar system.

And if we would know of the future, these same laws tell us that the history of our universe will end as it began, in cold and stillness and universal night. The matter in the solar system, instead of being infinitely diffused, will have gravitated into a solid mass. The energy which it once contained will have been radiated into the ether, which fills all space around. The energy of the matter of the universe, will have been transferred to the ether. Are these ether wavelets crossing and interlacing forever in reflection from some envelope which bounds our universe, and separates it from a fathomless, unknown beyond? or do they continue outward forever into a space which is absolutely without limit? Is our infinite the first of an infinite series of infinite spaces, having perhaps an increasingly higher order of magnitude?

The determination of the amount of heat radiated from the sun, per second, per unit of area, was attempted by Pouillet, and has been more accurately determined by Langley. This result has served as a basis for the determination of the duration of the life of our universe. There is some ground for thinking that this time interval may be determined with reasonable precision, but it is doubtful if such estimates can as yet receive much weight.

But a study of the flow of heat from the interior of the earth has enabled Sir William Thomson to determine between reasonable limits the interval since the earth began to solidify. The information needed for this is, the rate of increase in temperature with depth, and the conducting power of the material forming the outer shell of the earth. This result has attracted keen attention from geologists, for the interval found is much shorter than that formerly thought necessary to accomplish the work of geological time.

Another great step has been the increase in our knowledge of the ether. When the existence of an ether which filled all space was suggested, it was a conjecture based on possibility. The logical situation involved a choice between two theories of light. Newton had suggested that light might be a discharge of particles which shoot off from all luminous bodies, and which must travel with enormous speed. This condition has been strongly simulated in an artificial way in the interior of the Crookes tube. The cathode discharge falling upon the walls of the tube arouses the X-ray into activity, just as Newton thought the luminous particles might bombard the retina and arouse the sensation of light.

Many of Newton's followers were dogmatic in their adherence to his ideas. He was not.

Newton's ideas were held by a majority of the great men at the beginning of the century. But in the merciless examination which was given it the emission theory was found inadequate. At the beginning of the century Brewster was one of the foremost exponents of optics in England, and he strongly condemned the wave theory of light. He has placed upon record the statement that his "chief objection to the undulatory theory of light was that he could not think the Creator guilty of so clumsy a contrivance as the filling of space with ether in order to produce light."

In those days they tried to settle such questions by attorneys who argued, and ridiculed, and quoted authorities and precedents. Lord Brougham, who was a prominent figure of that day, made the most ludicrous efforts of this kind. He assailed Thomas Young, the great exponent of the wave theory, with the most bitter personalities. Lord Brougham's abilities and opportunities did not justify any well-grounded hope that he could know anything about a theory which must be tested by mathematical analysis and delicate experiment, but his powers of ridicule and invective were of a high order. For a time he prevailed with the British public as against Thomas Young. It was in 1801 that Young showed that Newton's rings and the colors of thin plates might be explained by the wave theory. Ten years later Fresnel gave the subject an elaborate mathematical discussion, and designed the most searching experimental tests, in which wave length was determined by interference phenomena. By the wave theory, it was easy to explain how the superposition of two luminous pencils might produce darkness. The advocates of Newton's ideas yielded very slowly, but the measurement of the velocity of light in various media gave the final evidence which could no longer be questioned. Newton's theory required that the velocity of light should be greater in matter than in a vacuum, and the reverse was found to be the case, as the wave theory demanded. The velocity of light was measured over terrestrial distances about the middle of the century. In 1850 Foucault measured the time required by light to travel over a distance of about 20 meters. This time is about $\frac{1}{150000000}$ second, an interval that bears about the same relation to the second that the second does to six months. And this minute interval of time is to be measured with precision.

This measurement was made possible by a method used by Wheatstone in determining the duration of an electric spark. A beam of light is reflected from a rapidly revolving mirror, to a distant fixed one, and is reflected back to the revolving one again, which has appreciably moved during this to and fro passage of the light. The beam emerging from the revolving mirror will be displaced from the entering beam, by an amount which will increase with the angular velocity of the mirror, and the distance between the two mirrors. The intermittent light thus reflected was also focused upon the tooth of a cogged wheel. When the wheel was driven at such a speed that successive teeth appeared at the focus at intervals equal to that of a rotation of the mirror, the wheel would seem to be at rest. If the wheel were slowed down slightly, it would seem to be rotating slowly in a direction opposite to that in which it was moving. If the wheel were slightly accelerated, it would have a slow apparent motion in the direction of its actual motion. This method gives a very accurate measurement of the time of rotation of the mirror and involves determining the number of rotations per second of the cogged wheel.

Michelson has made great improvements in Foucault's methods. With a slower rotation of the mirror, he obtained very much greater deviations of the returning beam. His first announcement of preliminary results was made in this city in 1878. In his final work the velocity of light was determined with a possible error of two hundredths of one per cent. This result has been universally accepted as the best attainable value.

The medium which transmits light is also concerned in the transmission of electrical and magnetic action. Faraday paved the way for this idea. He did not indeed concern himself with the nature of the ether, but he did abandon wholly the idea of action at a distance, which had formed a sufficient basis for mathematicians like Poisson and Gauss. His work between 1831 and 1841 resulted in establishing the idea that inductive action is communicated from point to point in space.

In 1850 Lamont of Munich established a periodicity in the average amount of daily oscillation in the magnetic needle. This fluctuation was due to a periodic change in the frequency of what have been called magnetic storms, with their attendant auroral displays. In 1851 Schwabe of Dessau established a period for sun-spot frequency. At once Sabine in England, Gautier in France, and Wolf in Switzerland, pointed out, independently of each other, the coincidence of sun-spot maxima and those of magnetic oscillation. On Aug. 3, 1872, Young observed at Sherman in the Rocky Mountains, three immense solar disturbances at intervals of about an hour, and the magnetic needle at that station was deflected entirely off the scale. The coincidence of the two phenomena could not be established because the time of the magnetic disturbance was not noted. But the Greenwich and Stonyhurst photographic records showed that the magnetic disturbances in England were felt at the same times that Young saw the luminous outbursts, where hundreds of dark lines in the spectrum were suddenly reversed for a few minutes at a time.

In the meantime Maxwell had been putting the ideas of Faraday into mathematical language. In his great treatise which appeared in 1873, he developed the idea that light was an electromagnetic induction, differing from that which an alternator may produce only in wave frequency, or wave length This view of the subject gave a complete explanation of the experimental results of Fresnel, according to which the so-called vibrations of light were in a plane at right angles to the direction of propagation of the ray. It also linked with the discovery of Oersted in 1820, that a magnetic line of force of a linear current is a circle, having some point on the current as a center. According to Maxwell, the electrical and magnetic lines of force, which are thus shown to be at right-angles to each other, are components of luminous vibration. Notwithstanding the long perspective of prior evidence tending to corroborate this view, Maxwell's ideas did not at first receive very general assent. But the electromagnetic theory of light has been steadily reinforced by every subsequent development. We can now see that the induced discharges which occur here and there on conductors remote from a great electrical discharge, are the spray over the sunken rocks, or the splashing surf along the shores of an ethereal ocean. It was Hertz who in 1888 first produced and studied by electrical means these ether waves which serve as the messengers in the wireless telegraphing of to-day. He stirred up the ethereal ocean by making electrical disturbance between spheres 30 cm. in diameter. The ether waves which he produced were 5.55 meters in length. When the disturbance is produced on smaller spheres, the wave-lengths are found to be shorter. In order to reduce the length of these Hertz waves to the length of light waves, so that they would become luminous, the bodies which are electrically disturbed must have dimensions such as Kelvin has computed for the atoms. An electrical disturbance of electrically charged atoms therefore involves the setting up of ether waves which affect the eye and which are called light waves. It is evident that in great solar outbursts, ether disturbances of large magnitude must be produced in order to account for the distortions of the earth's magnetic field, which are so frequent in the time of solar activity. It is possible that a blast from a great gun might have an appreciable effect upon a neighboring magnetic needle, of small moment of inertia and in a zero field.*

Spectrum analysis has been wholly developed during the last century. Fraunhofer discovered the dark lines in the solar spectrum in 1817. It was not until Bunsen and Kirschoff took up the matter about 1866 that the significance of the dark lines was suspected. Bright line spectra had been observed, and the coincidence of the dark lines of the solar spectrum with the bright lines due to certain metals, was finally found to indicate that the metals whose light was absent in sunlight, were present in the sun. The continuous spectrum is made up of an infinite series of overlapping images of the slit. The dark lines indicate that images are wanting. The particular light which iron vapors yield when heated has been partially quenched by the cool iron vapors lying above the most strongly luminous layers of the sun. These dark lines are displaced in the spectrum if either the radiating substance or the earth is in motion which changes the distance between the eye and the radiant mass. The phenomenon is precisely similar to the one in sound where

* This experiment yields appreciable effects, but it is so far complicated with the magnetic reaction of the steel barrel of the gun, and possibly with Rowland effects.

the apparent pitch of the sound is changed by motion of the sounding body or the ear. This has enabled astronomers to measure the velocity with which stars are approaching or receding from the earth. Double stars have been discovered which no telescope can resolve. The commingled light from the two stars has been separated by the spectroscope. The dark lines from the light of the approaching star, are deflected towards the violet end of the spectrum, and those from the receding star, are deflected in the opposite way. These deflections go through periodic to-and-fro changes, corresponding to the orbital motions around the common center of gravity. When August Comte said in his Positive Philosophy that while we might know the forms and distances of the heavenly bodies, "we can never know anything of their chemical or mineralogical condition," he really meant that chemists would never be able to have samples from these bodies collected and carted to Paris for analysis in test tubes. When Comte wrote these words the men were living who were to analyze the stars.

In the progress of the study of light, its identity with radiant heat was established. The earlier work by Melloni, Tyndall and Magnus was done with the thermo pile. The more recent work of Langley has greatly increased the delicacy of the measurements. Langley finds that only about one-fifth of the energy of the solar spectrum is from visible radiations. In the visible part of the spectrum, the luminous and heating effects rise and fall together. The dark lines are lines of lower temperature. The bolometer, which was designed by Langley for temperature measurements of this character, shows the presence of similar cold bands in the invisible part of the spectrum below the red. With the latest form of instrument, it is possible to measure to the millionth of a degree.

The greatest development shown in any one branch of Physics, has been in electricity and magnetism. The advances in our understanding of the nature of magnetic and electrical action have been already touched upon. Oersted, Arago and Ampère discovered that the space around a current of electricity is a magnetic field. They studied the directive action of currents upon magnetic needles, and upon other currents. Out of these studies grew the needle telegraph.

Sturgeon was the first to intensify the magnetic field of a current, by winding it in a coil around the legs of an iron bar bedt into the horse-shoe form. This was an electro-magnet. Joseph Henry produced an electro-magnet of enormous lifting force, and used small electro-magnets to send signals to a distant point. He connected his battery cells and designed the magnet-windings so as to make the signals effective over a long circuit. The telegraph line which he established at Albany made signals by means of the sound of the attracted armature striking a resonant stop. Some years later Morse added a system of recording apparatus, and built a line for commercial purposes. In practice the signals by means of sound were found more convenient than those which Morse tried to introduce.

During the greater part of the century, the source of electricity was the battery, of Volta and Galvani. But as early as 1831, Faraday had made the grand discovery, which was to work a revolution. On September 22 of that year he wrote in his laboratory note-book as follows: —

" I have had an iron ring made, (soft iron) iron round and $\frac{7}{8}$ of an inch thick, and ring six inches in diameter. Wound many coils of copper round, one half of the coil being separated by twine and calico. There were three lengths of wire, each about 24 feet long, and they could be connected as one length or as separate lengths. By trial of a trough, each was insulated from the other. We will call this side of the ring *A*. On the other side, but separated by an interval, was wound wire in two pieces, together amounting to about 60 feet in length, the direction being as with the other coils. This side call *B*.

" Charged a battery of ten plates, four inches square, made the coil on *B* side one coil and connected its extremities by a copper wire passing to a distance and just over a magnetic needle (three feet from wire ring). Then connected the ends of one of the pieces on *A* side with the battery; immediately a sensible effect on needle. It oscillated and settled at last in original position. On breaking connection of *A* side with the battery, again a disturbance of the needle."

Later he varied the experiment and writes: —

"In place of the indicating helix, our galvanometer was used, and then a sudden jerk was perceived when battery communication was *made* and *broken*, but it was so slight as to be scarcely visible. It was one way when made and the other way when broken, and the needle took up its natural position at intermediate times."

The device which Faraday describes was a transformer. The impulses which he saw in the needle were due to induced currents. He immediately proceeded to produce induced currents by the motion of a closed conductor, in a magnetic field. That was the first dynamo, and was constructed during the same month. If any person had asked of Faraday that exasperating question, what is the practical value of your discovery; how are induced currents available for money-getting? he would have been unable to make any satisfactory reply. The effects which he observed, were utterly insignificant. Who would then have imagined that these feeble impulses would some day transmit articulate speech? Who could have imagined the ponderous machinery now employed in pumping induced currents through massive conductors, to light large cities, and to move heavy cars loaded down with passengers? Even fifteen years ago the man who would have predicted that this city would contain the railway system which it now has, would have been considered a lunatic by every street railway man. It would have been sufficient answer to such folly, that there was no traffic to sustain such an enormous outlay of capital with the necessary running expense. It would have been called the idle fancy of a useless brain.

It became apparent in 1873 that the dynamo was reversible. The same machine might be mechanically driven and used as a generator, and it might be electrically driven in the reverse direction and develop power as a mechanical motor. This result had indeed been foreshadowed by Pacinotti in a remarkable paper in 1864. But his machine remained forgotten in the museum of the University of Pisa until the Gramme machine appeared in 1871. Pacinotti pointed out clearly that the dynamo and motor were complementary, but the reversibility of the Gramme dynamo as shown at the Vienna Exposition of 1873, and repeated at the Centennial Exposition at Philadelphia in 1876 was a most impressive lesson to all who saw it. Nevertheless it was not until 1880 that the scientific world was ready to admit that an enormous development of electrical industries was possible. It was then that the questions of economy were settled which showed the great economic advantage of the dynamo and the steam engine over the primary battery, and that large electrical plants with their high efficiency were possible.

The first telephone was constructed and operated by Philipp Reis in 1861 and 1862, and he gave his instrument the name telephone. His system consisted of a transmitter or loose contact which was disturbed by a membrane put into vibration by the sound wave, a receiving instrument consisting of an electromagnet or sounder upon a sounding board, and a battery. This is broadly, so far as it goes, a complete description of the telephone of to-day.

Bell modified the Reis receiver, making the armature in the form of an iron disc, and used the same instrument for a transmitter. In Bell's system, the sound waves were the source of power for setting the armature into vibration, such vibration by a dynamo action producing currents having the characteristics of the sound waves. In the Reis system the power was supplied by a battery, the current being moulded by the voice acting upon the loose contact in the transmitter.

The Reis instrument did not prove practical because the materials used were not the best that could be chosen. The membrane of his transmitter was of animal tissue, while iron is now used, and the loose contact was between platinum points, while carbon is now used. The Reis receiver was not sensitive enough.

The Bell system failed because the receiving instrument was not adapted to use as a transmitter, although his receiver was a great improvement upon that of Reis. The telephone of to-day is the improved Reis telephone. It is coming into more general use in the country than in the cities. In the great farming region of the upper Mississippi valley the farmers are everywhere building their own systems and owning their instruments. The value of such a service to a farming community is very great, and the financial advantage is not its most valuable feature.

The discovery of Roentgen in 1895 has taxed the ingenuity of every man who has sought to explain the nature of the X-ray. It was a discovery which lays hold of the secrets of the ether and the atom, and is likely to lead to results which as yet cannot even be conjectured. Becquerel and Madam Curie have found invisible radiations from various substances, which possess all the essential properties of the X-rays. It is said that Madam Curie is so saturated with radio-active matter, that she is barred from all laboratories where electrical work is being done. In her presence all electrified bodies are discharged. Another great discovery of the last decade was made by Zeeman of Holland. He found that if an incandescent gas whose spectrum is being examined, be placed in a strong magnetic field, the bright lines of the spectrum are resolved into component lines, which are plane polarized. Of the D lines given by sodium, D_1 becomes four lines, and D_2 becomes six. Lorenz has shown that this phenomenon is fully accounted for by the electromagnetic theory of light.

Even so fragmentary a review as this should contain some reference to the science and art of photography, which is wholly a product of the last century. Previous to the daguerreotype process, which was due to Daguerre and Nicéphore de Niepse, there was a process due to the latter, which yielded a permanent image on a metallic plate covered with an asphaltum varnish, which was then developed by means of a solvent. The time of exposure was from three to eight hours. The picture was in faint relief, the parts which had been most acted upon by the light being least acted upon by the developer.

The daguerreotype which was produced in 1839, was a picture, on a silver plate, or a copper plate coated with silver. The sensitive layer was formed by holding the plate in iodine vapor, and the image was then developed by holding the plate in mercury vapor. The vapor of mercury condensed upon the plate in proportion to the light action, so that the picture is a mercury amalgam. The plate was fixed by means of sodium hyposulphite. The time of exposure when only iodine was used in the preparation of the film was from three to thirty minutes, but this was very much shortened by the use of bromine in 1844. It was then possible to take so-called instantaneous views of well-lighted objects. A little later Fizeau treated the level plate with a solution of gold chloride mixed with sodium hyposulphite, which was warmed over a lamp until the plate had received the re-enforcement possible with this process. This produced a picture in slight relief, and most of the plates extant are of this class.

The wet plate collodion process which followed in 1850 possessed the advantage that prints could be made from the original negative, and that these prints show the object correctly as to right and left, which was not the case with the daguerreotype. Dry plates were first shown to be possible in 1854 by Gaudin. The dry-plate first became practically an assured success by the introduction of the alkaline developer, with films made sensitive by means of bromide and chloride of silver. This improvement is said to be of American origin, prior to 1862, but neither the date nor the author seems to be known. Up to 1880, pyrogallic acid was the sole reducing agent in the alkaline developer, but in that year Captain Abney discovered that hydrochinone was a most effective agent. From that time many other developers have been used. As an all-around developer pyrocatechin is probably the best yet discovered. There is a possibility that the future may see the elimination of the dark-room and the negative from photography, and the direct printing of positives from positives with short exposures.

If the history of the last century has taught us anything, it has established the practical or commercial value of research in pure science. It is from such work that all of the great achievements have directly come. And whenever any people forgets the source from which these great things have come, and allows engineering to supplant science, that people is on the way to the civilization of China. There are great problems yet to be solved. The burning of coal is a mere incident in human history. There are men now living who can remember when its use began, and there are boys now living who will see the beginning of the end. The substitution of some other source of heat and power for coal as it is now used, will tax the resources of the human race, if the civilization of to-day is to be maintained. It is customary to put away such thoughts with the optimistic remark that the men of the future will solve the problems of their time as we have solved the problems of our day. But it is also true that there have been former civilizations which have reached their culminations and vanished from the earth.

Nevertheless, the progress of science during the closing years of the century has been something marvelous, and we are amply warranted in looking forward for still greater things.

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THE PROGRESS MADE IN BOTANY DURING THE NINETEENTH CENTURY.

WILLIAM TRELEASE.

Issued November 26, 1901.

THE PROGRESS MADE IN BOTANY DURING THE NINETEENTH CENTURY.*

WILLIAM TRELEASE.

WHAT BOTANY STOOD FOR AT THE BEGINNING OF THE CENTURY.

At the beginning of the Nineteenth Century about 25,000 species of plants had been described, and, though considerable use had long been made of other species which at the beginning of the century were unclassified and unnamed by botanists, the number of these were relatively small, so that the entire knowledge of botany, economic as well as scientific, and in all of its branches, was practically confined to the limited number of species mentioned. This knowledge consisted in a recognition of their specific differences and the rather superficial affinities and relationship deduced from these in a great but often hopelessly scattered and frequently erroneous literature, and in popular acquaintance with their useful properties — particularly their medicinal virtues, and a general blocking out of their anatomy and physiology,— to no small extent a matter of subjective opinion.

SYSTEMATIC BOTANY.

About the middle of the preceding century, Linnaeus had elaborated a workable, if artificial, system of classification, which, with brief but sharp diagnoses, made it reasonably easy to ascertain whether a given species of plant in hand had been previously described or was new to science; and as he had combined with this the very simple expedient of referring to the several species by latinized binomials instead of by descriptive phrases, the naming and describing of species has proved not only one of the most necessary but also one of the easiest and most popular branches of this as well as of the related biologic science, zoology, during the century just closed.

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* An address delivered before The Academy of Science of St. Louis, November 8, 1901.

Linnaeus himself, in 1771, admitted 8551 species of plants, of which more than nine-tenths belong to the most obvious and grossly marked group, the flowering plants, which, with the ferns, still represent the field of botany for uneducated persons. The rapidity of progress in differentiating unrecognized species and characterizing such as had remained unobserved is shown by the increase of Linnaeus's scant 9,000 to some 70,000 before the first quarter of the Nineteenth Century had been passed, and, largely because of territorial exploration, the next half century produced even greater results and the phenomenal interest in the interior of Africa evinced during the closing decade of the century is to-day bearing like fruit. With this activity in collecting and naming plants came inevitably a progressive interest in the more and more difficult and minute flowerless plants, so that through the studies of Presl, Milde, the Hookers and others on ferns and their allies, of Schimper, Leitgeb and others on mosses and liverworts, of Agardh, Kuetzing, Harvey, Thuret and Bornet on algae, of Fries, Persoon, and the Tulasnes on fungi, and of Acharius and Nylander on lichens, the proportion of cryptogams to flowering plants gradually advanced, notwithstanding a very great increase in the latter, until at about the close of the third quarter of the century approximately one-fourth of the 125,000 species then known were cryptograms. Then came a much increased activity in the study of these minuter plants, partly from the concentration on them of study no longer believed to be necessary for the flowering plants of the more accessible parts of the world, these having been fairly satisfactorily disposed of on the grosser or so-called Linnaean ideas of specific limitation, and partly because of DeBary's studies of parasitism and a recognition that many of the diseases of cultivated plants are caused by fungi, the differentiation of which then became important from an economic as well as a systematic point of view. At the close of the century not far from 180,000 species of plants were known, of which some 75,000, or more than the total number of species known in all groups at the end of the first quarter of the century, are cryptogams. The last decade, however, has witnessed a proportionally greater increase in phanerogamic species than that marking the immediately preceding decades, because of the geographic exploration already referred to, and still more because of a growing change in the scale of specific differentials which has resulted in the segregation of many forms which under the older views passed for at the most varieties of polymorphic or variable species. The genera *Rubus* and *Hieracium*, in Europe, and *Viola*, *Sisyrinchium* and *Crataegus*, in our own country, well illustrate my meaning.

Just as the descriptive manuals of Linnaeus, and the editions of them published after his death by Schultz, Willdenow and others, facilitated and stimulated the accumulation of hitherto unrecognized species at the beginning of the century, its progress throughout has been recorded and accelerated by the publication of later works of the same general character and purpose. For the flowering plants, some of the most noteworthy of such general descriptive works are the incomplete Prodromus and Monographiae of the De Candolles, the numerous revisions of genera and families in Engler's Jahrbücher and the Journal of the Linnean Society, and the comprehensive Index Kewensis prepared by Mr. Jackson under a provision made in Darwin's will; and no account of this aspect of the science would be at all complete without reference to the books and journals devoted to the illustration of plants, foremost among which stands the Botanical Magazine, which, founded by Curtis in 1790, has been continued without interruption, and at the end of 1900 contained 7751 colored plates, mostly illustrative of plants of decorative value. For Pteridophytes, the manuals of Hooker and Baker have been most helpful. Bridel, Schimper and Warnstorf stand out prominent among those who have published comprehensive manuals of the Bryophytes, while the enormous Sylloge Fungorum of Saccardo and the as yet incomplete Sylloge Algarum of DeToni have made accessible the myriads of scattered descriptions of species belonging to these groups of the lower cryptogams.

SYSTEMS OF CLASSIFICATION.

The simplicity of Linnaeus's classification of flowering plants has been mentioned. The popular handbooks even of our own flora, up to a point somewhat after the middle of the century, were based on this system, which, when the purpose of the student was to find the name of a plant, has scarcely been equaled by any other; yet it had one very great defect, in that plants which were obviously related might come to stand far apart in it, so that the suggestion of this relationship would be lost on the user of a book in which it was followed. Even before the close of the preceding century, efforts had been turned to the arrangement of a natural sequence of the higher groups of plants, so that those which possess a number of important and correlated characters in common might be brought together, leaving the tracing of any given species to its place in the system for a quite independent artificial key, — the Linnean, for instance, or some other specially fancied by the writer or suited to his purposes. To the Jussieus the inception of this movement in a modern sense is due, and the elder DeCandolle stands out prominently among those who amplified and bettered it; and yet the success of these earlier seekers for a natural system was but partial, and in the summation of their conclusions, as exemplified, for instance, in the great Genera Plantarum of Bentham and Sir Joseph Hooker, though many of the resultant groups, even no higher than orders, possess a very puzzling complexity because of the insertion of aberrants, there still remain many, as, for instance, a large part of those constituting the so-called Apetalae, which are obviously little more than makeshifts, loose-jointed in themselves and with scarce concealed affiliations of the most diverse kinds. As early as the middle of the century, by his comparative developmental studies of the gymnosperms and higher cryptogams, Hofmeister laid the foundations of a more rational system, which, largely through the labors of Alexander Braun and Eichler, culminated in the phylogenetic system of Engler, which marks the close of the century.

Somewhat comparable needs and advances have marked the knowledge of the cryptogams. The ferns and their allies early differentiated themselves from the remainder of this great second group of Linnaeus, and the mosses and liverworts as quickly came to be recognized as forming another distinct group of primary importance in any natural classification, the researches of Hofmeister contributing largely to this result; but even to-day, convenience of treatment, if no other reason, causes specialists to write commonly on either algae, fungi or lichens, according to the group of thallophytes they may be studying. And yet the beginning of better things has been made, for DeBary's suggestion and Schwendener's morphological demonstration that lichens are in reality only certain fungi with enslaved or commensal algae as an integral and usually necessary part of their organization marks the close of the third quarter of the century, and in the concluding quarter various efforts have been made at a classification of the thallophytes on more scientific grounds than the presence or absence in them of chromophyll-bearing cells or tissues. Though the goal may not yet have been reached, these efforts are full of promise for success in the century that is now on the calendar.

EVOLUTION AND CLASSIFICATION.

It was in the first decade of the century that Lamarck, following a line of thought that had caused men long before his time to speculate on the varied forms of nature, attempted to show how environment, use and disuse of parts, and similar natural factors might have brought about modifications leading to the origin of new species from ancestors otherwise characterized; and the year 1858 will always stand out in prominence in the history of biology because of the simultaneous presentation in that year of almost identical explanations of the manner in which natural selection, or the survival of the fittest in life's struggle, might and of necessity must lead to the repeopling of a given territory by new forms descended from those pre-existing, provided, in the progress of time, the conditions of life were changeful and variations were present in offspring, as compared with one another and their parents, — as was well known to be the case. Darwin and Wallace, the authors of these first papers, did not go to the bottom of their great subject, and the last word on it is far from having been said yet, but the theory of organic evolution may be regarded to-day as an axiom on which most philosophical analyses of biology rest as a footing course.

Closely connected with the changing conceptions as to the origin and fixity of species, was a much increased interest in such evidence concerning the plants of the past as was afforded by their fossil remains, and, largely through the work of Brongniart, Goeppert, Heer, the elder Schimper, von Ettingshausen, Saporta and Solms Laubach, and Dawson, Newberry, and Lesquereux in this country, paleobotany has assumed, in the last fifty years, a position of no small importance.

Partly because of the same reasons, the geographical distribution of plants and the influences controlling widespread or restricted occurrence in the case of individual genera or species has also assumed an importance in recent years not formerly recognized for it, and on the foundation laid by DeCandolle, Humboldt and Martius, Grisebach, Engler, Drude and the younger Schimper have grounded a line of botanical research in which morphologists, systematists and evolutionists are alike interested.

With the change in the world's view of the fixity of species, and of their several and independent origin in their present form, came new and somewhat differently conceived efforts to group plants in a natural system, the ultimate object being virtually the production of a classification which should represent descent relationship as well as organic or morphological affinity, and which, in a word, should present the family tree of any individual group or species, — to the primitive animal and vegetable main divisions of which Haeckel in particular has given attention. A comparative glance at the Genera Plantarum of Bentham and Hooker, the synopses of Van Tieghem and Warming, and the still incomplete Pflanzenfamilien of Engler and Prantl will show how great have been the changes wrought in systems of classification by the introduction of these later considerations and motives. Free to read heredity and atavism into the explanation of aberrant minor characters, rudiments and vestiges, these men have often found in the minuter details of anatomy, reproduction and development most surprising indications of affinity between superficially and externally dissimilar groups. That they are not at one in their conclusions, indicates that the Twentieth

Century may regard the preparation of a truly natural system even of the higher plants as a part of its legitimate and necessary work, and it may well be that even though this task be accomplished, a like result among the lower cryptogams will be reserved for the next century. At any rate, although DeBary and others have contributed to a rational comparison of the larger groups of thallophytes, a glance at the sytematic memoirs relating to the fungi and algae shows a most obvious if convenient artificialty in their classification.

MORPHOLOGY AND ANATOMY.

Some years since, I saw with much interest a palm in the Botanical Garden of Padua on which, toward the end of the Eighteenth Century, the great poet Goethe made some of the observations which led to a formulation of his theory of metamorphosis in the parts of plants,— a theory which, in the first half of the century just closed, DeCandolle, our own Engelmann and others put upon a more scientific basis as a fundamental idea in plant morphology. Toward the middle of the century, the superficial indications afforded by position, gradation and malformation of parts were much strengthened by embryological and developmental studies, and it was about this time that the details of cellular structure, grossly known for a couple of centuries, were brought out by Robert Brown and Schleiden, the latter of whom stated in another form for plants the general fact of the origin of every cell from a previous cell, succinctly expressed by the now venerable Virchow, whose eightieth birthday has recently been celebrated in this country as well as in his native land; for by this time these structures had come to be recognized as the seat of vital manifestations through their protoplasm, which, discovered and named by von Mohl, and the nuclear differentiation of which was observed by Robert Brown in 1835, and which was shown to be similar in animals and plants by Cohn in 1850, Huxley has so happily designated as the physical basis of life.

Though external morphology and anatomy, the latter even in some of its minuter details, had come down from the past, both may be said to have been made a part of science in the Nineteenth Century, and the fact that homologous members may serve the most diverse organic purpose, that sometimes analagous organs, like the leaf of the moss and that of the flowering plant, cannot be morphologically compared, since they are parts of fundamentally unlike plant bodies, shown primarily by Hofmeister's discovery of alternating generations in 1851 (one representing the gametophyte and the other the sporophyte of beings with alternating sexual and non-sexual generations), and that cells, cellular tissues, and systems of such tissues show a similar and comparable pliability in their adaptation to physiological function, as Haberland and others have made clearly evident, with many other facts of equal importance for a right understanding of nature, may be credited in large part to the last half, and, as to much of their detail, to the last quarter, of the century. Indeed, the consideration of tissues from a proper morphological point of view dates practically from Hanstein's studies in 1868, and their rational terminology was established by DeBary nearly a decade later.

Though initially wrong, Schleiden as early as 1837 laid the foundation of embryology in botany, and the organogenetic studies of Hofmeister, Payer, Sachs and Goebel will always stand as classics in the application of the developmental line of research to the progressively formed grosser parts of more mature plants.

PHYSIOLOGY.

Physiology, either of animals or plants, could scarcely have become a science before the determination of the grosser chemical composition of the atmosphere, which, made by the chemist Priestley toward the end of the Eighteenth Century, was quickly followed up by him, Ingen-Housz, de Saussure, Hales and numerous others, with the result of showing that a very considerable part of the organic matter of which plants consist is derived from the carbon dioxide of the atmosphere, which is fixed in carbohydrate form in the green parts of plants under the influence of light; and the studies of Draper and Wilhelm Engelmann stand out in prominence as contributing to our present knowledge that certain wavelengths of sunlight, when passing through the chlorophyll or comparable pigments of plants, disappear as light, and are converted into chemical or physical energy, which, under the guidance of the living protoplasm of the cells, is utilized for the breaking down of carbon dioxide and water, their elements being then recombined into the organic products referred to, the most usually recognizable of which is starch. An attendant liberation of oxygen, constituting, with the abstraction of carbon dioxide, a purification of the air, so far as the needs of animals are concerned, was made known shortly before the century began, but it is to Saussure, at its very beginning, that the connection of this with actual plant nutrition is due, and it was he, too, who gave the first clear demonstration that the remainder of plant food is derived from the soil. A detailed study of this subject, as well as of the metabolism or elaboration and transmutation that food undergoes in the plant in its various nutritive and storage processes, occupied particularly Sachs during the third quarter, and Pfeffer during the last quarter of the century, Pfeffer's ingenious investigation of the osmotic action of root hairs being particularly interesting in connection with the physical problems of the absorption of crude materials and the retention of organic products in the self-same organ. The last half of the century has also produced the demonstration, on a large scale in the field experiments of Gilbert and Lawes, and on a smaller scale, but under more rigid control, in the laboratories of numerous investigators, of the fact that while free atmospheric nitrogen is not available for the nutrition of higher plants, which therefore as a rule require for their proper support an abundance of available nitrogen supplied to the roots in the form of nitrates, nitrites, etc., the Leguminosae as a class make use of large quantities of this atmospheric nitrogen, not, indeed, in its free form directly, but through the intervention of certain of the lowest fungi which inhabit their roots as parasites, but, having the power of assimilating nitrogen in forms in which it is not usable by the higher plants, contribute to the latter enough of the product of their own activity to more than compensate for whatever injury they may cause by their parasitic invasion of the tissues of the host. Indeed, pure cultures of these pseudo-parasites are on the market, under the name of nitragin, for the inoculation of new soil when sown to clover and other leguminous crops, though it must be added that the practical value of this inoculation is thrown in considerable doubt by recently made laboratory experimental tests.

PROTOPLASM.

Doubtless the most important of all discoveries in physiology is that of protoplasm as the living working part of both plants and animals, in the early phases of which von Mohl, Robert Brown, Naegeli and Cohn played a prominent part. Studies on this substance, its physical and chemical properties, and its activity, have occupied many of the best chemical, physical and biological investigators of the last half of the century, and are destined to be the keystone of physiological attainments in the century we are now entering upon.

Though sex in the flowering plants was known long before the century opened, to the extent that the co-operation of stamen and pistil, and even the transfer of pollen from the former to the latter, was recognized as necessary for the production of fertile seed,— a fact, indeed, which Linnaeus indicated and even amplified in his designation of the groups which he called phanerogams and cryptogams,— it was not until 1823 that Amici observed the growth of the pollen tube to the ovule, and real fertilization, the union of protoplasmic structures, was not demonstrated until the close of another quarter of a century, when Hofmeister and Pringsheim at intervals of a few years described it respectively for some of the higher and lower cryptogams.

The greatest advance in protoplasmic study was doubtless made possible by Strasburger's introduction, in 1875, of methods for fixing protoplasmic structures in certain desired states of their transformations, by the use of killing and hardening fluids, and the addition a few years later of differential staining processes, as a result of which, largely through his efforts and those of his pupils, the minutiae of both cell division and cell union have been carried to a wonderful detail,— perhaps the least expected result of which is the closing discovery of the century of an unexplained double fertilization in the case of the flowering plants, by which the endosperm is formed as well as the embryo.

How protoplasm carries "life," the nature of the reactions t shows to stimuli of various kinds, causing it to work, to change, to rest, to die, how it is moved to vary in the forms of tissues and organs over the construction of which it presides, how it transmits characters of form and action from parent to offspring and reverts now and then to ancestral structures and traits in both animals and plants, are scarce more than question marks on an otherwise clean page spread out before the Twentieth Century, and it is not possible yet to say whether they will receive their answer soon or always remain unanswered.

ECOLOGY.

One of the most popular lines of physiological work to-day concerns itself with special modifications and activities connected with local environment and what may be called the personal or individual needs of plants, in contrast with their needs as a class. This is called biology by some and ecology by others.

Just before the end of the Eighteenth Century, a German, Sprengel, observed a few hairs springing from the base of the petals of a wild geranium, and, though he did not share the impersonal teleological views that prevail to-day, he believed that these hairs existed for a purpose, which he undertook to find out. Under them he found glands secreting a sweet fluid, nectar, which he saw was sheltered by them, but the nectar was a further puzzle. Bees came to the flowers as he watched, and removed the nectar, which the glands had secreted and the hairs protected for them, and the question seemed answered; for an idea, somewhat prevalent even yet, that everything exists for the good of something else, — generally higher in the scale than itself, — was commonly held in his day. Further observation, however, showed him that the bees became dusted with pollen and that they unconsciously transferred some of this to the stigmas of the flowers, while rifling them of their sweets, and that this transfer, long known as necessary in some manner for fertilization and the quickening of the germ, could not otherwise take place except by remote chance. Then he examined many other kinds of flowers, and reached the broad conclusion that nectar in these organs exists for the sole purpose of attracting to them insects, sometimes of one, sometimes of another kind (for which it is protected from rain and dew and commonly from other classes of insects, and to which its presence is made known by odor and color, and its position by grooves and other guiding mechanism and by variegation in the coloring), which, while serving their own purposes, ensure the pollination of some flowers which might attain the same end directly as well of others which from some seeming freak of nature mature stamens and pistils at different times or even have them separated in different flowers, — sometimes, even, on different individuals. A half century later, Mr. Darwin, seeing in floral forms, colors and odors something more than means of overcoming chance defects in plan or development, showed not only the general accuracy of Sprengel's conclusions as illustrated by a host of other cases, but that they might be carried a step further, by stating the purpose of the structural and functional peculiarities in question to be the effecting of cross fertilization. Then he set to work to prove, by a long-continued series of experiments, whether or not this is connected with a gain to the offspring resulting from such crosses, and we cannot question the resulting conclusion that it is. Indeed it may be asked if any axiom is more important to an understanding of the evolutionary adaptation of species to changing environment than the obvious conclusion that sex, and particularly the partition of the sexes with secondary provisions of the most varied kinds for their functional union, is a most potent factor for the introduction of variation within helpful limits, on which natural selection may build with the current of the times, as well as for the direct betterment of the offspring.

How dissemination is effected, and the structures connected with it; how plants may climb to the light and air with a minimum expenditure of material, over their more robust competitors when the latter have reached their own limit in the occupation of the soil; how they may feed upon each other and upon animals; how they may extend into deserts and the salt sea: — these and many other questions show the range of ecology as it is now occupying alike physiologists, morphologists and systematists, and, while much remains to be done, its blocking out is likely to stand as one of the more important achievements of the century just closed.

APPLIED BOTANY.

Hand in hand with the advance of pure botany, and largely dependent upon it, have gone at least as great advances in the application of ascertained facts; and the best agricultural practice of to-day, as exemplified in the intelligent use of fertilizers, the rotation of crops, etc., is conformed to the teachings of vegetable physiology, while the knowledge of the plasticity of plants has made each of the later decades the recipient of numerous improved races and varieties of cultivated species. To-day, among the more pliable forms, within certain limits that cannot yet be overstepped, new varieties suited to special needs are selected and bred by men like Burbank with surprising rapidity and accuracy, almost to drawing and specification, because of the practical application of the knowledge that plants are plastic under environment and selection.

The details of other contributions of botanical science to human needs are of no less interest. Modern brewing is carried on scientifically, as a result of the fermentation studies of Schwann and Pasteur and the cultural investigations of Hansen, a yeast being employed which has developed from a single cell of known pedigree and properties. Citric acid and vinegar are produced with equal certainty if less complexity of manipulation, and the method of pure cultures of the necessary ferments is coming into considerable use in the ripening of cream for butter and of cheese.

Perhaps the most markedly useful application of the botanical knowledge of the century is in the field of medicine. In the early part of the century, the physician was of necessity a botanist, and indeed many of the botanists whose names appear in this account were physicians by training. From the Middle Ages he had the knowledge of physic that characterizes primitive man everywhere to-day, and this had gradually come to represent a pseudo-science of therapy which he practiced by diagnosis, prescription and exhibition,— if I may borrow a word. But the century just closed has seen a differentiation of pharmacy from medicine which has not only greatly simplified the materia medica through its more careful investigation, but has given the physician more freedom to follow out his own field, so that to-day, while he must know experimentally the physiological action of more plants than his predecessors actually used, he need not ordinarily know more of these plants than that their active principles, in sulphates, fluid extracts and the like are commercially procurable in definite degrees of assimilability and concentration, though his final trials have not been lessened thereby.

The century will forever stand as that in the last third of which the germ causation of disease was made known, and the names of Pasteur, Koch and Lister are inseparably connected with this great addition to knowledge, which,— since the germs of disease are for the most part bacteria, that, though of simple and aberrant structure, are commonly classed with plants, — must be counted among the achievements of botany. Sanitation and surgery have both been put on an entirely new footing by this recognition that the minutest organisms yet known are responsible for many of the most dreaded pests, so that the exclusion or elimination of germs, and the use of their own products,— either direct or by animal reaction in the form of serums,— in therapy, form to-day the surest safeguard against infectious disease, the occurrence of which may soon be regarded as almost a stigma on civilization.

The century just closed has witnessed an almost equal advance in knowledge of the causation of the diseases of plants themselves. Rusts, smuts and mildews are no longer looked upon as exanthemata, but the fruits of parasitic fungi, which, more than is the case with the parasites of animals, are of the less minute and therefore more easily seen and controlled groups,— though plants are also subject to a few bacterial diseases. Much has been done in the way of prophylaxis, and something in the way of germicide therapy, in this field, and the foundations of a true science of plant pathology based upon distorted physiological processes due to improper environment, food and the like, or to the ferments secreted by parasites or the chemical alterations which these induce in the affected plants, may be said to have been laid in the closing days of the century by Professor Marshall Ward.

POPULARIZATION AND PUBLICATION.

The development of any department of science is closely connected with its power of interesting men. The present tendency of this interest is more and more commercial and economic, though it should be said at the same time that no earlier period has witnessed a higher development of interest in the purely abstract problems of science.

The lucid, terse Latin of Linnaeus did much to popularize the botany of his time, and for the century just closed full credit should not be withheld from those whose writings fostered and spread an interest in their science. Schleiden, Lindley, Willkomm, Gray, Darwin, Kerner von Marilaun, Gibson and Lubbock have shown pre-eminent ability to perpetuate the old and awaken new interests. Too great value can scarcely be attributed further to the scientific stimulus and opportunity due to the publication of such comprehensive class-books as the general text-book of Sachs, the Comparative Anatomy of DeBary, the physiological manuals of Sachs and Pfeffer, the pollination works of Herman Mueller and the dissemination treatises of Haberland, all of them original contributions to science as well as adaptations of its results to the purpose of the teacher; and the abridgments, local adaptations, popularizations and imitations of these products of leaders, reaching and being comprehended by a larger audience, may perhaps have done even more toward fanning into flame the first spark of enthusiasm and desire for research.

Quite as noteworthy is the advance in educational and instructional methods, and appliances other than books. Up to the middle of the century, instruction in botany was confined to more or less perfunctory lecture courses, and the pupil who would become an investigator was obliged to work out his own salvation, or was permitted as a special favor the privilege of association with a master. The opening of a botanical laboratory at the Univerity of Freiburg, by DeBary, in 1858, marks an epoch. It is a poor college to-day, as the equipment of colleges now goes, which has not a better laboratory and a better equipped one than was DeBary's. With the introduction of laboratory work came the training, in the laboratories, of laboratory teachers to spread the leaven, not only by repeating the process but by publishing in detail their methods for the benefit of others who could not work under them. It would be impossible to overstate our debt to Huxley and Martin's Biology and the many guides of which it was the precursor, to Strasburger's Practicum, the various treatises on microscopic technique and microchemistry, and the increasing number of physiological handbooks which have grown out of Detmer's original. That the botanical world has to-day not only the attainments of its predecessors, but as a regular institution these facilities which did not formerly exist for the performance of work, may perhaps be regarded as affording ground for the hope that the century upon which we have now entered will as greatly surpass in achievement the one just closed as the latter did all of its predecessors.

BOTANY IN THE UNITED STATES.

Though epitomized in the preceding general survey of the field, the progress in our country of what has been called the amiable science interests us so directly that I may briefly touch on it in conclusion.

Systematic phanerogamic botany, early advanced through the labors of Nuttall, Pursh, the Michaux, Elliott and others, made rapid strides about the middle of the century, when Torrey and Gray undertook the publication of their Flora, — unfortunately never completed, partly because of the wealth of new material brought to its authors as a result of the extensive explorations of our western territory undertaken by the Government. Without mentioning others who have greatly contributed to its advancement in recent years, I may say that Gray's Manual, Chapman's Flora of the Southern States, Watson's contributions to western botany, Coulter's Rocky Mountain Botany, and the masterly revisions of critical groups by Gray, Watson and Engelmann, have brought a knowledge of our plants within the reach alike of investigator and amateur; while few countries possess a local flora comparable with that of Britton and Brown, and the great Silva of Sargent, now nearly completed, stands quite alone. Eaton and Engelmann laid a good foundation for the further study of pteridophytes, which Davenport, Robinson, Underwood and others have later brought to the hands of every working botanist. Through the work of Sullivant, Lesquereux, James, Austin, Barnes and Underwood, the bryophytes have been similarly put within easy reach, though the current work of Mrs. Britton, Evans, Renauld and Cardot shows that even more than with the superior groups, the field for systematic research is here still open. By the publications of Harvey, Farlow, Collins and others on marine forms, and of Wood, Wolle and others on those of fresh water, our algae have been exceptionally well blocked out. Tuckermann, Willey and Williams have brought the lichens together; and though less advanced than either of the others, the great group of fungi, because of its size, has been the subject of more actual work than all of the remaining cryptogams, and the names of Berkeley, an Enlishman, and of Schweinitz, Curtis, Ravenel, Farlow, Thaxter, Peck and Ellis stand out prominent among those who have contributed to its lasting literature. Like the great English botanists, Americans have been closer adherents to the DeCandolle classification of flowering plants than to the later French and German systems until very recently; but the disposition of to-day is strongly toward the latter. I may mention, in passing, that the new plantations of the Missouri Botanical Garden will be twofold, — one portion illustrating the now familiar but rapidly passing French-English system, while another and greater part will follow the general lines of the present German school.

Americans were quick to take up the Darwinian ideas of evolution, — none quicker than the great botanist Asa Gray, and it may not be going too far if I say that nowhere in the world has horticultural advantage been more fully taken of their teaching than in America, Bailey's varied work in this field being particularly mentionable.

Though morphological teachings were prevalent in the middle part of the century, as a research subject morphology has been confined to the later years, during which, in connection with more precise anatomical studies, it has contributed to an important if not very extensive literature, — largely, it must be confessed, resting upon the studies of German-trained students.

Vegetable physiology, as a subject for serious work in this country, can scarcely be traced back of the last quarter of the century, except for the much earlier isolated studies of Draper; but to-day the force of several well-equipped laboratories, and numerous isolated workers, are probing the difficult problems the solution of which could not be compassed in the century just closed. Nowhere has that phase of physiological work known as bionomics or ecology been more eagerly taken up than in this country, and, beginning with Dr. Gray, a number of workers have enlarged our knowledge of the pollination, dissemination and germination of plants, while the last few years have witnessed a widespread and growing interest in the vegetative relations of plants to their surroundings, and in the manner in which, as individuals and communities, they compete for a foothold on the earth.

Without going into details, I may say that America leads the world in the attention given to botanical (as other) research relating to agriculture and horticulture, and no small part of the recent progress in this field has come from our Government and State laboratories and experiment stations.

In conclusion, as, perhaps, the greatest advance in botany made in this country during the century, I may note the increase and improvement in means and methods for instruction. The great strides made in this direction by the Germans at the close of the Franco-Prussian war, and the prestige of DeBary, Sachs, Pfeffer and Strasburger in their Universities, stimulated and attracted Americans to such an extent that to-day no country, aside from Germany, offers so many, so good, or so varied opportunities for training in scientific botany as we possess in the United States, and a rich fruition may be confidently expected in the century on which we have now entered.

Issued November 26, 1901.

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Transactions of The Academy of Science of St. Louis.

VOL. XI. No. 8.

SOME INTERESTING MOLLUSCAN MONSTROSITIES.

FRANK COLLINS BAKER.

Issued November 26, 1901.

SOME INTERESTING MOLLUSCAN MONSTROSITIES.*

FRANK COLLINS BAKER.

The study of abnormal and pathologic specimens of the Mollusca is of great importance in assisting us to understand the biological causes for the specific variation of our fresh water shells. Monstrosities among land and fresh water shells are constantly occurring and are, curiously enough, more often produced by external causes, as man or cattle, than by the atrophy or hypertrophy of any part of the animal.

Fords and shallow bars of rivers and lakes are the best localities in which to find abnormal individuals, as in these places cattle and horses are passing to and fro and injuring the shells with their feet.

Several years ago Mr. Charles E. Beecher, in a paper on Abnormal Fresh-water Shells,† made the following statement (p. 55): —

"Specimens similar to the preceding briefly noted forms are often overlooked or considered unimportant by many collectors; but to a student of morphological variations and possible specific change, they are extremely interesting. After numerous accidental and natural changes have been illustrated and described, embracing many genera and species, it will be possible to generalize important biological facts relating to the classification of species and manner of growth of the organisms."

The following descriptions and figures are a contribution toward this end.

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* Presented by title before The Academy of Science of St. Louis, November 18, 1901.

† Annual Report New York State Museum of Natural History. **36**: 51. 1883.

Lampsilis alata Say.

Pl. XI. f. 1, 1a.

Figure 1 illustrates the interior of the right valve of the specimen. A fold starts 15 mill. from the umbo and extends to the lower margin of the shell where it ends in a bell-shaped expansion; the fold is 45 mill. long and the greatest diameter is 22 mill. Near the starting-point there is a projection which forms a large bunch extending into the cavity of the shell. The left valve (fig. 1a) is normal, except for a slight constriction which extends across the shell in a direction parallel with the fold in the right valve.

The writer is quite unable to explain the cause of this malformation. Some peculiar accident must have occurred to the shell to have caused such a peculiar mode of growth. Within the bell-shaped fold the epidermis is formed, but it is rougher than that of the rest of the shell. The breadth of the shell is greater than in a normal specimen of this species and the posterior margin is more rounded. The posterior basal portion of the shell projects far below the normal ventral margin of the shell, as in female specimens of *Lampsilis luteola*.

Length 87.00; Height 65.00; breadth 34.00 mill.

Lampsilis ligamentina Lamarck.

Pl. XI. f. 3, 5.

A single specimen of this species seems to have been crushed in on the posterior end of both valves, probably by the feet of horses or cattle. This injury caused a hole on each side of the shell, 40 mill. behind the umbones, which the animal neatly repaired by the addition of new shelly matter. The injury to the left valve was greater than to the right, the shell being pushed in to such an extent as to make an oblong hole at the anterior edge of the posterior adductor muscle scar. It is notable that the epidermis formed about the injured region is much coarser than that on the normal part of the shell and is raised in fine ridges. This seems to be a general rule in such cases.

Length 85.50; height 56.00; breadth 43.50 mill.

Another specimen of this species (a right valve, fig. 3) is abnormally thickened and ridged internally by the addition of pearly matter, evidently to cover some foreign substance which found entrance between the valve and the mantle of the animal. The additional material is confined to the region bounded by the muscle scars, and the pallial line and hinge. A part of the posterior adductor muscle (posterior end) is covered by a thick callus, and the anterior adductor muscle scar is strengthened by the addition of numerous pearly pustules.

Length, 106.00; height, 63.00; the thickness of one valve 15.00 mill.

Weight of a normal valve of same size 2.45 oz.

Weight of abnormal valve 3.75 oz.

UNIO GIBBOSUS Barnes.

Pl. XI. f. 2, 4.

Monstrosities apparently occur in this species more than in any other, it seeming to be especially susceptible to abnormalities. One specimen (fig. 2) has the shell twisted on the hinge line, causing the anterior end of the right valve to be depressed below that of the left valve. The latter has a depression which extends from the umbo to the ventral margin and there is a corresponding swelling in the right valve. The right valve has two lateral teeth or laminæ, one about 12 mill. long, smooth, extending a short distance behind the cardinal teeth and the normal lamina, which is triangular and very rough. The teeth of the left valve appear to be normal. Interior of shell white.

Length 88.50; height 42.00; breadth 33.50 mill.

Another specimen of this species (fig. 4) has the posterior basal portion produced as in the females of some species of Lampsilis. The nacre of this specimen is a beautiful mauve or purple.

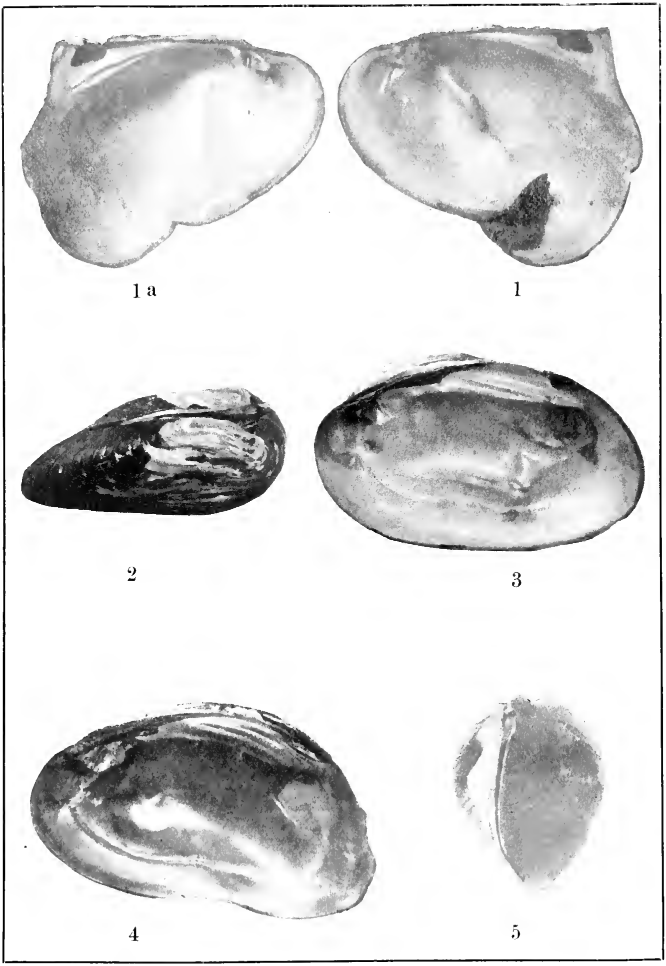
Several Unios recently collected bear patches of pearly secretions resembling little piles of agglutinated sand, and indeed these without doubt are small grains of sand covered with pearly matter. These masses are placed in different parts of the shell, some being outside of the pallial line, some near the cavity of the beaks and others near the adductor muscles. The specimens figured were collected by Mr. Joseph Kinstler in the Mississippi River, while pearl hunting.

EXPLANATION OF ILLUSTRATIONS.

Plate XI.

1, *Lampsilis alata* Say; 1a, right valve of same, showing fold. — 2, *Unio gibbosus* Barnes. — 3, *Lampsilis ligamentina* Lamarck. — 4, *Unio gibbosus* Barnes. — 5, *Lampsilis ligamentina* Lamarck.

Issued November 26, 1901.



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Transactions of The Academy of Science of St. Louis.

VOL. XI. No. 9.

KINDERHOOK FAUNAL STUDIES.

III. THE FAUNAS OF BEDS NO. 3 TO NO. 7 AT BURLINGTON, IOWA.

STUART WELLER.

Issued December 18, 1901.

KINDERHOOK FAUNAL STUDIES. III. THE FAUNAS OF BEDS NO. 3 TO NO. 7 AT BURLINGTON, IOWA.*

STUART WELLER.

INTRODUCTION.

In the second paper of this series of Kinderhook Faunal Studies† the fauna of the Chonopectus sandstone, or bed No. 2 in the Burlington section, was described. The present paper contains descriptions of the faunas of all the beds in the same section lying above the Chonopectus sandstone and below the Burlington limestone. These two papers, therefore, will cover the entire series of Kinderhook faunas at Burlington, which were long ago investigated by White,‡ White and Whitfield, § and Winchell, ¶ and most of the species described by these men are here illustrated from the type specimens preserved in the University of Michigan collection. There still remains to be described a single member of the series of fossil faunas at Burlington, that of bed No. 1, a fauna that was unknown to the earlier investigators.

In these studies it is not presumed that the fauna of any one of these beds has been exhaustively investigated. Future collections will certainly bring to light additional species in each of the faunas which have been described, but each fauna has been here treated as fully as the material at hand, from several different sources, would admit, and it is believed that enough has been presented to materially assist in the correlation of the faunas with those from other localities.

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* Presented by title before The Academy of Science of St. Louis, November 18, 1901.

† Trans. Acad. Sci. St. Louis. **10.** No. 3.

‡ Proc. Bost. Soc. Nat. Hist. **9 :** 8–33. (1862.)

§ Proc. Bost. Soc. Nat. Hist. **8 :** 289–306. (1862.)

¶ Proc. Acad. Nat. Sci. Phil. **1863 :** 2–25. — Proc. Acad. Nat. Sci. Phil. **1865 :** 109–133.

As this paper is not devoted to the description of the fauna from a single bed, but to the description of a series of faunas, the descriptions of species have been grouped under five headings, each section being devoted to the fauna of a single stratum. The general conclusions which have been reached through the study of these faunas have been reserved for treatment at the end, subsequent to the detailed descriptions of all the faunas.

The source of the materials upon which the faunal studies of this paper have been based has been the same as in the case of the Chonopectus sandstone fauna. The most important collection consulted is that known as the "White Collection" in the museum of the University of Michigan, for the use of which the author is deeply indebted to Prof. I. C. Russell. Another small collection was contributed by Prof. S. Calvin, State Geologist of Iowa, and still other material has been collected in the field by the author. Assistance has also been given by Dr. E. O. Hovey, of the American Museum of Natural History in New York City, through whose courtesy the writer was enabled to examine the Burlington material in that museum.

Description of Species.*

In many cases the descriptions of species published in the present paper, are in the main copies of the original descriptions. In all cases these copied descriptions have been placed in quotation marks, although some slight changes have often been introduced, especially in the case of the brachiopods where the terms pedicle and brachial are introduced instead of ventral and dorsal, and the modern usage of the terms foramen, delthyrium, etc., is substituted in those cases where it has been found necessary. In all cases measurements have been changed from fractions of an inch to millimeters.

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* The Bibliographic references have been omitted from these descriptions. For these the reader is referred to Bulletin 153, U. S. Geological Survey, "A Bibliographic Index of North American Carboniferous Invertebrates," by Stuart Weller, Washington, 1898. When species are referred to a different genus in this paper than in Bulletin 153, a reference is given to the Bulletin.

I. THE FAUNA OF BED NO. 3.

Bed No. 3 never attains a thickness of more than a few inches, but there are often two distinct bands represented. The lowest of these is an impure limestone crowded with individuals of *Chonetes gregarius.* The upper one is an impure oolitic limestone. The Chonetes band is apparently persistent throughout the area around about Burlington, but the oolite band is often wanting. With the exception of *Chonopectus fischeri*, the species which have been recognized in these two bands have in no case been found to be common to both, so it is possible that the two should not be considered as members of one bed; but because of their extreme thinness and because the upper band is not always present, it has been thought best to group them together, although the species from each will be considered separately.

All the material from the Chonetes band used in the preparation of the present paper, has been collected by the writer, while all the material from the oolite band belongs in the University of Michigan collection. Further careful collecting in the field will doubtless increase the number of species from each band.

Species from the Chonetes band.

MOLLUSCOIDEA.

BRACHIOPODA.

CHONETES GREGARIUS n. sp.

Pl. XII. f. 2.

Shell small, transversely suboval, hinge-line a little shorter than the greatest width. Pedicle valve rather strongly convex, the fullness extending well out towards the cardinal and lateral margins, so that this portion of the shell is but moderately compressed. Brachial valve much flatter than the opposite one.

Surface marked by exceedingly fine, radiating striae, from 90 to 100 being recognizable upon an average pedicle valve. The characters of the cardinal spines not observed.

The dimensions of an average specimen are, length 4½ mm.; breadth 6 mm.; and convexity 1 mm.

Remarks. This little species occurs in vast numbers in the thin Chonetes bed of the Burlington section. In general outline and in size it resembles *C. geniculatus* White, from the Louisiana limestone, but it differs conspicuously from the latter in its much finer and far more numerous radiating striae. It also resembles *C. scitulus* Hall from the middle and upper Devonian faunas of New York, but is usually smaller and always has much finer radiating striae. White seems to have identified the species provisionally with his *C. geniculatus*, at least he records Burlington, Iowa, with a query, as one of the localities for his species, and there seems to be no other species of the genus at this locality which could have been indicated by such a reference. Casts, believed to belong to this species, are present in the Chonopectus sandstone beds,* but the conditions of preservation are not such as to preserve the delicate surface markings.

CHONOPECTUS FISCHERI (N. & P.)

Pl. XII. f. 1.

A few imperfect specimens of this typical Chonopectus sandstone species have been observed in the thin Chonetes bed, but none of them are as well preserved as those from the limestone bed No. 4.

RHIPIDOMELLA BURLINGTONENSIS (Hall).

Pl. XII. f. 3.

A single, nearly perfect specimen of a brachial valve of this species has been collected from the thin Chonetes bed in the Burlington section. It does not differ in any essential particulars from individuals of the same species found at other localities and in other horizons.

PUGUAX STRIATOCOSTATA (M. & W.).

Fragments of this species agreeing in all respects with the typical form found in bed No. 4, have been observed in the Chonetes bed.

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* Trans. Ac. Sci. St. Louis. **10**: 68.

Species from the Oolite band.

ECHINODERMATA.

Numerous fragments of crinoid stems, belonging to several different species, are present in this bed, but no determinable portions have been observed.

MOLLUSCOIDEA.

BRACHIOPODA.

ORTHOTHETES sp. undet.

An imperfect specimen belonging to a member of this genus has been noticed. It is possibly a representation of one of the species of *Orthothetes* which occur elsewhere in the Kinderhook beds at Burlington, but it is too fragmentary for certain specific identification.

RHIPIDOMELLA sp. undet.

A single imperfect specimen of a small subcircular species of this genus has been observed. Its size is about 10 mm. in both length and width.

CHONETES sp. — cf. C. ILLINOISENSIS Worthen.

A single specimen of *Chonetes* which may possibly belong to the species *C. illinoisensis*, has been observed in the material from this bed. Additional material is necessary, however, for certain specific identification.

CHONOPECTUS FISCHERI (N. & P.).

This species sometimes occurs in the oolite band of bed No. 3, it being the only species of the band, as far as observed, which is also present in other faunas of the section.

MOLLUSCA.

PELECYPODA.

AVICULOPECTEN IOWENSIS Miller.

Pl. XII. f. 9.

Original Description. "Shell small, appressed, hinge-line equal to greatest width; anterior and posterior umbonal ridges at right angles, and straight to the middle of the shell extremities, between which the pallial margin is regularly curved. Wings distinct, the anterior slightly inflated, rounded at the extremity, and separated from the body of the shell by a rather acute notch, from which a furrow extends to the beak; posterior wing flattened, acute, subtriangular, with a shallow sinus below. Body of shell smooth; wings with radiating ribs, strongest on the anterior wing and crossed by equally strong concentric lines; posterior wing with fine concentric lines."

Length of hinge-line in the type specimen 6½ mm., height of shell about 7 mm.

Remarks. This species was originally named *A. occidentalis* by Winchell, but that name being preoccupied, it was changed to *A. iowensis* by Miller in his work on North American Geology and Paleontology. The only individual which has been examined is the single type specimen in the University of Michigan collection. The perfectly smooth body of the shell is the chief peculiarity of the species, but this may be due to an eroded condition of the type.

AVICULOPECTEN sp. undet.

An imperfect specimen about 14 mm. in height has been observed from this bed, which is apparently distinct from *A. iowensis*, but the single individual is too imperfect for identification or definition.

MICRODON LEPTOGASTER (Win.).

Pl. XII. f. 8.

Sanguinolaria leptogaster. Bull. U. S. G. S. 153: 537.

Original Description. "Shell small, thin, subquadrangular. Beaks subcentral, flat, not elevated above the dorsal line. Posterior end obliquely truncated; anterior gently rounded below, abruptly above, with a long deep lunette; ventral side arcuate in the middle, joining the extremities by a gradually increased curvature. Umbo flattened, — a low ridge extending obliquely to the posterior basal angle. Dorsal line straight behind the beaks, joining the posterior side at an angle of 125°. Surface marked by fine regular striae parallel with the ventral and posterior margins."

Length of type specimen 14 mm., height $9\frac{1}{2}$ mm., convexity of one valve about 2 mm.

Remarks. This little shell seems certainly to be cogeneric with those species in the Spergen Hill fauna of Indiana, and with those in the New York Devonian faunas, which are referred to the genus Microdon.

GASTEROPODA.

Holopea conica Win.

Pl. XII. f. 4–7.

Shell small, never exceeding 10 mm. in height and usually not more than 5 mm. Spire elevated; whorls gradually and regularly increasing in size, probably about seven or eight in the adult shells, though usually not more than four or five are preserved, the apical ones being destroyed. Suture distinct, moderately impressed. Aperture subcircular in outline, somewhat angular posteriorly, but regularly rounded in front. The outer lip thin, inner lip slightly thickened, surface of shell smooth. The dimensions of one of the best preserved specimens, the type of *Holopella mira* Win., are, height $5\frac{1}{2}$ mm., diameter of body whorl 3 mm.

Remarks. Winchell has described separate individuals of a little coiled shell, which occurs gregariously in this stratum, as three distinct species, *Holopea conica*, *Holopea subconica*, and *Holopella mira*, but a careful examination of all the type specimens and numerous others has led to the decision that all of them constitute a single species, the various specimens exhibiting different stages of growth. The proper generic reference of the species is not certain, but it does not have the circular aperture of *Holopella*, and is for the present retained in the genus *Holopea*, though the adult shells possess a more elevated spire than is usually present in members of that genus. The specific name retained is *conica*, that being the first species described, although all of them were published in the same paper.

Loxonema sp. undet.

A single imperfect individual of a species apparently belonging to this genus, has been noticed. When complete it must have been about 25 mm. in length, with a maximum diameter of 10 mm.

STRAPAROLLUS? sp. undet.

Several imperfect specimens of one or more species of low coiled shells, having diameters of 5 or 6 mm., have been observed. They are too imperfect to allow their generic characters to be certainly determined, but they seem to belong to Straparollus.

CEPHALOPODA.

ORTHOCERAS sp. undet.

A single imperfect individual of a gradually tapering species of this genus, is preserved in the collection studied. Its greatest diameter is 6 mm., and the length of the fragment preserved is about 14 mm.

II. THE FAUNA OF BED NO. 4.

MOLLUSCOIDEA.

BRACHIOPODA.

CHONOPECTUS FISCHERI (N. & P.).

Pl. XIII. f. 17.

This species occurs in the fauna of bed No. 4, but never in such abundance as in the Chonopectus sandstone. The specimens are not casts as in the sandstone, and often preserve the fine surface markings which cannot be seen in the sandstone specimens. These markings consist of exceedingly fine, more or less interrupted radiating striae, and still finer concentric striae with some coarser wrinkles of growth. The double set of curved diagonal lines seen in many of the casts are not so conspicuous in these limestone specimens, but they seem to be more pronounced on the brachial than on the pedicle valves.

PUGNAX STRIATOCOSTATA (M. & W.).

Pl. XIII. f. 14-16.

Original description. "Shell attaining a medium size, subtrigonal, or sometimes approaching subpentagonal, mod erately gibbous, about as long as wide, or sometimes slightly wider than long; greatest breadth near the middle; posterior lateral slopes rather straight, and converging to the beaks at an angle of about 100 degrees; sides more or less rounded or sometimes subtruncate. Pedicle valve depressed-convex in the umbonal and lateral regions, and concave in the middle, the concavity commencing narrow and shallow, generally behind the middle, and widening and deepening to the front, so as to form a broad, shallow, rather flat mesial sinus; depressed part of the front curving downwards, and a little produced, to fill a corresponding sinuosity in the front of the other valve, the margins of the two valves meeting there, at rather less than a right angle, so that no emargination of the outline of the front is produced; beak small, rather pointed, projecting little beyond that of the other valve, over which it curves. Brachial valve considerably more convex than the other, the greatest convexity being generally in front of the middle, from which it rounds off abruptly behind and on each side, while in the middle it rises into a broad depressed, or moderately prominent, flattened or somewhat rounded, mesial prominence, rarely extending back much beyond the middle; beak incurved; cardinal margin broadly and rather distinctly sinuous on each side of the beak.

"Surface ornamented by about nine to eleven broad, distinct, rounded, occasionally bifurcating plications, most of which, excepting the outer lateral ones, extend nearly to the umbones. Of these plications, three to four occupy the mesial sinus and four to five the mesial fold, the greater number in each instance generally resulting from the bifurcation of one of the lateral ones. Distinct, rather coarse, irregular radiating striae also mark every part of the surface, and are well defined on exfoliated surfaces, as well as upon internal casts, while fine undulating lines, and occasional stronger marks of growth, traverse the surface concentrically.

"Length of a mature specimen 24 mm.; breadth 25 mm.; convexity $17\frac{1}{2}$ mm.; also of another more gibbous individual, of the same size, 19 mm."

Remarks. The specimens of this species from bed No. 4 agree exactly with the typical form of the species as it was originally described by Meek and Worthen from Kinderhook, Illinois. Another variety of the species or perhaps a form which should be considered as a distinct species, occurs in the Chonopectus sandstone,* but it always differs from this typical form in having a much wider angle at the beak and is a larger and thicker shell. In the illustrations of the species on Plate XIII. the fine radiating striae which are so characteristic of the shell, are not shown.

CAMAROTOECHIA? HETEROPSIS (Win.).

Pl. XIII. f. 9-13.

Rhynchonella heteropsis, Bull. U. S. G. S. 153: 533.

Original description. "Shell small, varying from sectoriform to transversely elliptic, with moderately projecting beak; very young specimens in the shape of a barley-corn. Plications sharp, ranging in number from ten to twenty; of which three generally (sometimes two or four) occupy the sinus of the pedicle valve. This valve has a moderately sharp beak, turned back in an angle of 45° with the plane of the shell, and slit (in the cast) from the apex to the hinge; sinus deep toward the front of the mature shell, wanting in the young one; the plications on each side of the sinus variable, four in those with two plications in the sinus, six, seven or eight in those with three, and five in those with four, making the whole number of plications ten to nineteen. These lateral plications are bent backwards in approaching the margin. Greatest prominence of pedicle valve near the beak. Brachial valve more ventricose than the pedicle, most prominent at the anterior margin; mesial fold much less marked than the sinus opposite, consisting of two, three, four or five plications, elevated at their extremities somewhat above the lateral plications, the remotest of which exhibit a strong downward curvature. Beak of this valve concealed beneath that of its fellow."

"Length $9\frac{1}{2}$ mm., breadth $10\frac{1}{2}$ mm., thickness of both valves 7 mm.

Remarks. This species is remarkably variable in form. The commonest variety is a moderately flattened shell with

* Trans Ac. Sci. St. Louis. **10**: 72.

pointed beak, having three plications in the sinus; a less common form being much thicker with the sinus produced into a lingual extension at the front of the shell. This last variety approaches very closely to *Rhynchopora pustulosa*, but the shell structure is not punctate as in that species. The little specimen described by Winchell as *Rhynchonella unica* (see Plate XIII. figs. 7–8) is only a small distorted specimen of this species, its peculiar characters being due to the lateral crushing of the type specimen.

RHYNCHOPORA PUSTULOSA (White).

Pl. XIII. f. 4–6.

Original description. "Shell subtrigonal or subglobose, front broadly rounded or slightly flattened, sides flattened and meeting at the beak at nearly a right angle. Brachial valve much more convex than the pedicle valve, which is usually somewhat depressed; beak closely incurved, highest part near the front margin. Beak of pedicle valve prominent, acute and considerably incurved; delthyrium triangular.

"Surface marked by from twelve to sixteen strong, somewhat rounded plications, three of which are usually moderately depressed on the pedicle valve, and four elevated on the brachial valve, forming the mesial fold and sinus, which are not observable much more than half the length of the shell. Along the center of each of the plications, for a considerable distance from the margin, runs a slight depression, giving them a flattened appearance.

"Fine concentric striae and imbricating lines of growth are visible on well-preserved specimens. When the shell is partially exfoliated it usually presents under the lens a fine pustulose appearance."

The dimensions of a rather large specimen are: length 12 mm.; breadth 14 mm.; thickness 10 mm.

Remarks. The types of this species closely resemble some individuals of *Camarotoechia ? heteropsis*, and from the form of the shell alone it would probably be impracticable to separate these two species. All the authentic specimens of this species, however, exhibit the finely punctate shell structure of *Rhynchopora*, while authentic specimens of *C. heteropsis* are apparently impunctate.

In his original description White recorded this species from most of the beds of the Kinderhook at Burlington. The types, however, are without exception from bed No. 4, and the rhynchonelloid shells from other beds do not possess characters which seem to warrant their specific identity with these.

SYRINGOTHYRIS HALLI Win.

Pl. XIII. f. 1-3.

Original description. "Shell of medium size, transversely elongate, widest along the hinge-line; greatest depth of the two valves equalling or exceeding the greatest length. Pedicle valve with a deep, defined sinus; beak very elevated; surface sloping thence with but little convexity, to all parts of the margin, — being sometimes even concave between the apex and the cardinal extremities; area large, triangular, transversely striate, flat or slightly arched, with a more marked incurvation just beneath the beak; perforated by a narrow, or moderately wide, triangular fissure, which is grooved along its lateral borders as if for the reception of a deltidium; dental plates rather short, diverging at an angle of 66°; mesial septum a low ridge extending two-fifths the length of the valve; line of divaricator scars extending with a curve from the inner end of dental plates to inner end of mesial septum. Brachial valve moderately ventricose, with a convex surface, and abrupt well-defined mesial elevation, and a small beak which overhangs the base of the fissure in the area of the opposite valve, — the area being scarcely perceptible in the brachial valve. Surface ornamented by 12 to 16 rounded ribs on each side of the mesial fold and sinus, becoming obsolete toward the lateral angles. Mesial fold and sinus destitute of ribs. The whole surface is further marked by faint, delicate lines of growth."

"Length of hinge-line 33 mm.; depth from beak of pedicle valve to most prominent point of brachial — which is nearly at right angles to the plane of the valves — 17½ mm.; distance from hinge-line to middle of anterior margin 13½ mm.; elevation of area 12 mm.; width of fissure at base 7 mm."

Remarks. The individual here illustrated is the most perfect one of the five type specimens in the University of Michigan collection, but it is somewhat smaller than the one whose dimensions are given by Winchell. The author of the species included in it as a variety, a shell from the Chonopectus sandstone below, which, however, proves to be specifically distinct, being the same species for which Hall proposed the name *Spirifer extenuatus.* The differences between the two species have already been noted in the description of the Chonopectus sandstone fauna.* The median septum mentioned by Winchell in his description is scarcely worthy of being mentioned as such, it being nothing more than a very slight ridge dividing the two lobes of the diductor muscular impressions. In none of the type specimens could the punctate shell structure of this genus be distinguished. The presence of a canaliferous plate is exhibited in one internal cast included among the types, which may have been collected from some other bed.

III. THE FAUNA OF BED NO. 5.

MOLLUSCOIDEA.

BRACHIOPODA.

LEPTAENA RHOMBOIDALIS (Wilck.).

Pl. XIV. f. 19-20.

This cosmopolitan species has not been observed below this horizon in the Kinderhook section at Burlington. The specimens need no comment, they being similar to those occurring elsewhere.

ORTHOTHETES INAEQUALIS (Hall).

Pl. XIV. f. 16-18.

Original description. "Shell subplano-convex or depressed hemispherical, semi-elliptical in outline; hinge line equalling the greatest width of the shell. Brachial valve very gibbous, greatest convexity near the center; umbo promi-

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* Trans. Ac. Sci. St. Louis. **10**: 77.

nent, beak scarcely elevated above the hinge margin. Pedicle valve nearly plain, slightly convex towards the beak, flattened at the lateral margins, and slightly concave towards the basal margin which is not sinuate; area long, narrow; delthyrium broad."

"Surface marked by alternating larger and smaller striae, which in the casts appear to be fasciculate near the margins, striae curved upwards on the margin of the convex valve, but not running out on the hinge line."

The dimensions of an average specimen are, length 19 mm., width 22 mm., convexity of brachial valve 6 mm.

Remarks. This species is closely allied to *O. chemungensis* of the New York Devonian faunas. Its form is more regular than in most of the species of the genus, but it does exhibit some variation, especially in the length of the hinge-line which is often shorter than the width of the shell. The pedicle valve is more variable than the brachial and has a greater resemblance to *O. chemungensis.*

PRODUCTUS ARCUATUS Hall.

Pl. XIV. f. 23.

This species is rarely represented in this fauna, its normal position being in the oolitic limestone above. The specimens which have been observed are all imperfect, but they retain the general form, proportion and markings of the species and are probably identical with those in the oolite bed.

PRODUCTUS PARVULUS Win.

Pl. XIV. f. 21-22.

Original description. "Shell very small, semi-elliptic or nearly semicircular in outline, with a hinge-line equalling the greatest width, or a little less. Pedicle valve ventricose, with regular, though slightly diminishing curvature from beak to anterior margin, describing an arc of about 180°; beak elevated above the hinge-line and incurved over it; flanks regularly convex, abruptly flattened and auriculate at the hinge extremities. Brachial valve unknown. Surface ornamented with small, rigid, continuous, radiating ribs, which on the sides increase by implantation."

Length of an average example $6\frac{1}{2}$ mm., breadth $6\frac{1}{2}$ mm., convexity of pedicle valve 3 mm.

Remarks. The size of this species varies somewhat, the measurements given above being taken from a medium-sized individual. The largest specimen observed has a length of 9 mm.

PRODUCTUS MORBILLIANUS Win.

Pl. XIV. f. 24–25.

Original description. "Shell small, transversely subelliptic, only moderately produced. Hinge line seven-eighths the greatest width of the shell; ears small, nearly right-angled. The shell regularly contracts from the aperture to the beak, which is small, subacute, and projects slightly beyond the hinge. The arching of the shell is such that when resting on the aperture the greatest height is equal to one-half the greatest width. No sinus or flattening present. The surface is marked by a series of deep, continuous, equidistant wrinkles, ten or eleven in number, becoming obscure toward the beak; between the wrinkles are numerous fine concentric striae not easily seen without a magnifier. These features are crossed by a longitudinal system which, near the beak, is a set of fine regular costae, which near the middle become interrupted by the wrinkles, and, losing their identity, result in several concentric bands of short longitudinal tubes buried in the substance of the shell, and gradually emerging and presenting their apertures anteriorly."

Width of specimen illustrated 29 mm., length 26 mm., greatest convexity $7\frac{1}{2}$ mm.

Remarks. The original description of this species was made from a specimen coming from the base of the Burlington limestone at Burlington, Iowa, but another specimen from bed No. 5 is said to be "probably identical with this." This sandstone specimen mentioned by Winchell is preserved in the "White Collection" with the label marked "Type in part," and it is this specimen which is here illustrated and whose dimensions are given. Judging from the dimensions given by Winchell, this specimen is about twice the size of that from the base of the Burlington limestone, and its relative convexity is only about one-half as great.

Camarophorella lenticularis (W. & W.).

Pl. XIV. f. 11-13.

Original description. "Shell small, broadly ovate, or subcircular, length and breadth nearly equal, profile lentiform. Valves subequal, depressed convex. Beaks small, pointed, slightly incurved, sides and front regularly rounded. Pedicle valve a little the most convex; the beak pointed, and projecting beyond that of the dorsal. Spondylium of the interior of the ventral valve proportionally large, in some specimens nearly one-third the width of the shell, and extending about one-third the length of the valve; longitudinal septum reaching to near the center of the shell. Interior of brachial valve with a single longitudinal septum, with horizontal plates curving toward the cavity of the opposite valve. Strong radiating muscular or vascular markings appear on internal casts of both valves."

"Surface apparently smooth, without mesial fold or sinus."

Length of an average pedicle valve 12 mm., breadth $10\frac{1}{2}$ mm.; dimensions of a brachial valve, length $10\frac{1}{2}$ mm., breadth 12 mm.; thickness of a specimen 11 mm. long and 10 mm. wide, 6 mm.

Dielasma allei (Win.).

Pl. XIV. f. 10.

Centronella allei, Bull. U. S. G. S. 153: 171.

Original description. "Shell large to medium size, terebratuliform, greatest width a little anterior to the middle, contained one and one-fourth times in the greatest length. Pedicle valve somewhat ventricose, full to the immediate vicinity of the margin, especially along the cardinal slopes; regularly arching from beak to anterior margin; highest in the middle; anterior margin with a barely perceptible truncation; no sinus or fold present; beak produced beyond that of brachial valve, truncated and circularly perforate at the extremity; dental lamellae more than one-fifth the whole length of the valve; muscular scars, consisting of one faint median linear impression, on each side of which is another, all reaching to the middle of the valve. Brachial valve with its short imperforate beak closely concealed under that of its fellow, slightly truncate in front, but without mesial fold or sinus; regularly arched from beak to front, highest in the middle, exhibiting a convexity equal to that of the opposite valve. Muscular scars consisting of a faint but distinct linear median impression, with a much deeper linear impression on each side, and a very faint one exterior to each of these — the three principal impressions reaching to the middle of the valve. Shell thin, stony and solid; structure beautifully punctate under a lens; general surface polished, marked by a few feeble concentric lines of growth."

Length of type specimen 17 mm., breadth 11 mm., convexity of pedicle valve 5 mm.

Remarks. The type specimens of this species are from bed No. 5 and from the overlying oolitic limestone. The original description of the pedicle valve was made from an internal cast from the sandstone, the brachial valve and the shell structure being described from an oolitic limestone specimen. The specimen illustrated is the type of the pedicle valve.

In the original description this species was referred to the genus *Centronella*. The brachidium has never been observed but it is extremely probable that the species is a *Dielasma*. It is referred to this latter genus here because it has the general form of other members of the genus and does not so closely resemble members of the genus *Centronella*.

SPIRIFER CENTRONATUS Win.

Pl. XIV. f. 3-4.

Shell broadly subtriangular in outline, hinge-line extended, with mucronate cardinal extremities, breadth along the hinge-line usually more than twice the length of the shell. Pedicle valve much more convex than the brachial, the greatest convexity being at a point in about the middle of the valve, the slopes from this point to the cardinal extremities, concave; beak pointed and incurved; sinus rather narrow, sharply defined and subangular at the beak, becoming rounded towards the front, with one median plication starting near the beak and extending without division to the anterior margin; the bounding plications of the sinus are larger than any others on the valve, they divide at a point about one-third the distance from the beak and each one gives off from its inner side a single branch which occupies the lateral slope of the sinus; cardinal area narrow, with subparallel margins. Brachial valve depressed convex, flattened toward the cardinal extremities; the fold but slightly elevated above the general surface of the valve, usually marked by a single furrow along its median line, rarely with a lateral one on each side. Surface of each valve marked by twelve to sixteen simple, rounded plications on each lateral slope, and by concentric, lamellose lines of growth which become more crowded near the margin and of which a few are usually stronger than the others. These concentric markings can only be observed in external impressions of the shell.

The dimensions of an average specimen are: length $11\frac{1}{2}$ mm., breadth along hinge-line 25 mm., convexity of pedicle valve 5 mm.

Remarks. The Burlington specimens of this species were originally included by Hall, along with specimens from the Chonopectus sandstone, in his species *S. biplicatus*. The specimens from these two horizons are specifically distinct, however, and the Chonopectus sandstone shell has been retained as the typical *S. biplicatus*. Immature individuals of the brachial valves of *S. centronatus*, as for example the specimen here illustrated, often have some resemblance to *S. biplicatus*, but the pedicle valves of the two species need never be confused. *S. centronatus*, although it has an elongate hinge-line with mucronate extremities, never possesses the excessively elongate and attenuate cardinal extremities which are characteristic of *S. biplicatus*.

S. centronatus was originally described from the Waverly series of Ohio, but neither the original specimen nor other specimens from the same region, have ever been illustrated. The species has been identified, however, from Nevada, Utah, and the Yellowstone Park, and good illustrations of specimens from these localities have been published. The Burlington specimens agree well with the original description of the species, and with the published illustrations of western specimens. The species is closely allied to *S. marionensis*, but differs from that species in its smaller size and in its more extended hinge-line.

Spirifer marionensis Shum.

Pl. XIV. f. 1–2.

The specimens of this species in the upper yellow sandstone are not common, but those that have been observed are indistinguishable from specimens in the superjacent oolite bed where the species becomes much more abundant.

Spirifer peculiaris Shum. ?

Pl. XIV. f. 6–9.

Shell subcircular to longitudinally subsemielliptical in outline. Length of hinge-line usually less than the width of the shell in front, the cardinal extremities usually rounded. Valves subequally convex. Greatest convexity of pedicle valve posterior to the middle of the shell; beak small, pointed and incurved; umbo prominent; sinus narrow, sharply defined near the beak, but becoming less distinct and relatively shallow anteriorly, in the casts often ill defined throughout, and sometimes indicated only by a flattening of the shell along the median line; cardinal area concave, its margin rounded in the casts. Brachial valve regularly convex, fold but slightly elevated above the general surface of the shell. Lateral slopes of each valve marked by six to eight simple, depressed, rounded plications which decrease regularly in size from the fold and sinus to the lateral margins; in the casts the plications are often obsolete or nearly so; the fold and sinus without plications.

A rather large cast of a pedicle valve measures 16 mm. in length and 19 mm. in width. If the shell were preserved, the length would be increased considerably, much more in proportion than the width. Most of the specimens from the upper yellow sandstone are smaller than the one whose dimensions have been given, the length of the shell usually being less than 15 mm.

Remarks. The only specimen observed which preserves the external features of this shell is a wax impression taken from a natural mold in the University of Michigan collection. In this specimen the hinge-line is somewhat longer than the width of shell in front, and the margin of the cardinal area is angular and not rounded as in the casts. The internal cast of the same individual is also preserved in the same collection and does not differ from other similar specimens.

In authentic specimens of *S. peculiaris* from the Chouteau limestone of Cooper County, Missouri, the margin of the cardinal area is always rounded and the hinge-line shorter than the greatest width of the shell. These Chouteau specimens are also, for the most part, internal casts, and they may have had a better defined cardinal area in the shell itself, but the length of the hinge could not have been greater than the greatest width of the shell in any of the specimens which have been examined. If the extended hinge-line be a constant characteristic of the Burlington specimens, they will have to be considered as distinct from *S. peculiaris*, but sufficient material to establish this distinction has not been available for study.

The plications of the pedicle valve in the Chouteau limestone specimens, are always better defined than in any of the Burlington specimens, but this may be due to the different sediments in which they are preserved.

RETICULARIA COOPERENSIS (Swallow).

Pl. XIV. f. 14-15.

Original description of Spirifer hirtus. "Shell of medium size, extremely ventricose, about once and a half as wide as high. Hinge-line very short, not more than one-third as long as the width of the shell, front and cardinal angles regularly rounded. Pedicle valve most ventricose a little forward of the beak, which is obtuse and incurved; area scarcely perceptible; delthyrium broad, triangular, nearly as wide at the base as the length of the area; front half of the valve marked by a broad, shallow, undefined sinus. Brachial valve less ventricose than the opposite, regularly convex, without a visible mesial elevation; beak obtuse, incurved, extending above the cardinal line."

"Surface marked by strong, equidistant, concentric ridges, indicating different stages of growth; also by indistinct, radiating striae, which form little pustules at the margin of the ridges, as if for the attachment of setae. No appearance of plications has been observed on any of several specimens examined."

Length of an average specimen 15 mm., breadth 19 mm., convexity of pedicle valve 5 mm.

Remarks. *Spirifer hirtus* W. & W., described from bed No. 5 at Burlington, is a synonym of the species described from the Chouteau limestone of Cooper County, Missouri, as *S. cooperensis* Swall. The species is a common one in the fauna under consideration and is scarcely more than a diminutive form of *R. pseudolineata* (Hall) from the Osage faunas. The median septum and dental plates of the pedicle valve, represented by narrow slits in the specimens, are conspicuous features of the species as it occurs in the yellow sandstone in the form of internal casts. The brachial valve is marked only by a somewhat faint median septum.

CYRTINA ACUTIROSTRIS (Shum.) ?

Pl. XIV. f. 5.

This species is represented by a single specimen of a brachial valve. It agrees in all respects, except such as may be due to differences of preservation, with specimens from the Louisiana limestone. Additional specimens, however, showing the opposite valve, will be necessary for study before this identification can be made with certainty.

MOLLUSCA.

PELECYPODA.

PTERINOPECTEN NODOCOSTATUS (W. & W.).

Pl. XV. f. 7.

Aviculopecten nodocostatus, Bull. U. S. G. S. 153: 113.

Original description. "Shell of medium size, semi-circular in outline, valves depressed convex. Hinge line straight, equalling the greatest width of the shell. Anterior extension separated from the body of the shell by a deep marginal sinus, and by a broad flattened depression on the surface, extending from the beak to the extremity of the auricle; posterior side having no sinus. Beak of the right valve minute, depressed, situated at two-fifths of the length of the hinge from the anterior extremity."

"Surface marked by from forty-five to fifty rugose, radiating plications, which sometimes bifurcate; those on the body of the shell about twice as wide as the interspaces; while those on the sides are much finer. The depression, separating the anterior auricle on the right valve, has but one plication. Strong, undulating concentric lines cross the radii, giving them their rugose surface."

The dimensions of the type specimen are, length 27 mm., and height 17 mm.

Remarks. It has already been shown * that the two type specimens of White and Whitfield's *Aviculopecten nodocostatus* are really representatives of two distinct species, and one of these species from the Chonopectus sandstone has been provisionally referred to *Pterinopecten laetus* Hall. The specimen which is retained as the type of *P. nodocostatus* is from the upper yellow sandstone and is the only example which has been observed. The original description of the species was based for the most part upon this specimen, and in the preceding copy of this description all references to the left valve, which was the Chonopectus sandstone specimen, have been omitted.

PERNOPECTEN COOPERENSIS (Shum.).

Pl. XV. f. 5–6.

A description and discussion of this species has already been published in Kinderhook Faunal Studies. I.† One of the specimens here illustrated is one of the types used by White and Whitfield for their species *Aviculopecten limaformis*, and the other, the one showing the crenate hinge, is the specimen used by Winchell as the type of his genus *Pernopecten*.

LITHOPHAGA MINUTA n. sp.

Pl. XV. f. 19.

Shell minute, the type specimen having a length of 9½

* Trans. Acad. Sci. St. Louis. **10** : 84.

† Trans. Acad. Sci. St. Louis. **9** : 24.

mm., and a maximum width near the posterior extremity of 4 mm; subcuneate in outline, anterior extremity sharply and narrowly rounded; posterior extremity broadly rounded, dorsal margin straight, ventral margin slightly convex; the beaks situated above the anterior extremity; the hinge-line nearly equalling the extreme length of the shell. Extending from the beak to the posterior basal extremity is a well-developed umbonal ridge which is rather sharply rounded anteriorly but becomes more broadly rounded posteriorly; the dorsal slope from the umbonal ridge is nearly vertical and slightly concave near the beak, but becomes less abrupt and slightly convex posteriorly; the ventral slope is convex throughout; the greatest convexity of the shell is upon the umbonal ridge about one-third the length of the shell from the beak.

Remarks. This little shell is apparently cogeneric with several species in the American Mississippian faunas, which have usually been referred to the genus *Lithophaga*. It is quite possible that these shells are not really members of Lamarck's genus, but they may be retained here for the present for the want of a better place for them. DeKoninck has referred several quite similar species from the Carboniferous fauna of Belgium, to the genus *Modiola*.

MACRODON PARVUS W. & W.

Pl. XV. f. 14.

Original description. "Shell small, elongate quadrangular, or arca-form; length equal to twice and a half the breadth. Valves extremely ventricose. Beaks prominent and incurved, situated at about two-fifths of the entire length from the anterior end. Hinge line straight, nearly as long as the body of the shell. Posterior end obliquely truncate, somewhat prolonged at the postero-basal angle. Anterior end gradually rounding from the hinge on to the basal margin, which is gently arcuate, with a slight emargination in the middle, forming a small byssal opening. Hinge plate narrow, bearing on the posterior end two long linear, lateral teeth; the inner one the longest, reaching nearly one-third the length of the shell; the anterior end having about four short, oblique teeth, but less distinct than those of the posterior. Anterior muscular scar subcircular, situated near the upper anterior angle. Posterior scar larger than the anterior, with its upper margin excavated out of the hinge plate. Pallial line entire, connecting the muscular scars."

"Surface smooth, except a few concentric undulations, which are scarcely visible except on the upper side of the posterior umbonal slope."

Dimensions of one of the type specimens: length 11 mm., height 7 mm., convexity of one valve 2 mm.

Remarks. This is a common species of the fauna. The concentric markings of the shell are perhaps a little more strongly marked than the original description indicates, and the muscular impressions are always faint and are usually not recognizable at all. The basal margin is often straight with no indication of a slight emargination.

EDMONDIA NUPTIALIS Win.

Pl. XV. f. 13.

Original description. "Shell of moderate size, transversely-suboval; in adult specimens considerably inflated in the vicinity of the pallial border. Beaks subcentral, small, incurved, somewhat elevated above the moderately extended, slightly arcuate hinge-line. Ventral margin gently curved or nearly straight in the middle, more rapidly curved toward the rounded, subequal extremities. Hinge structure obscure, but apparently consisting of one or more lateral teeth on each side of the beak. Surface unequally and interruptedly furrowed. Greatest thickness through the middle of the shell."

The dimensions of the type specimen are: length 20 mm., height 16 mm., and convexity of one valve 6 mm.

EDMONDIA STRIGILLATA Win.

Pl. XV. f. 12.

Original description. "Shell rather small, rather gibbous, transversely oval; beaks subcentral, elevated, obtuse, somewhat strongly turned forward. Ventral margin gently arcuate in the middle, more rapidly curved toward the neatly rounded extremities, of which the posterior is broadest. Hinge-line curved, furnished with a pair of rather thick lateral teeth; cardinal teeth apparently none. Surface marked, toward the margin, by a few irregular concentric wrinkles."

Length 20 mm., height $15\frac{1}{2}$ mm., convexity of a single valve 5 mm.

Remarks. In the original description this species is said to be marked by "fine radiating lines," but this statement is omitted from the above quotation. The types of the species are three in number, but one of these, the one showing the radiating lines, is not even cogeneric with the others. The dissimilarity between this specimen and the other two was probably recognized by Winchell subsequent to the preparation of the description of the species, for this specimen is indicated on the card to which all three are attached, "*Dexiobia whitei*" and the specimen may be a left valve of this species. Of the two remaining specimens, a drawing has been made of the best preserved one, and is here published. It is very similar to *E. nuptialis*, and in all probability *E. strigillata* should be considered only as a synonym of that species.

Sphenotus cylindricus (Win.).

Pl. XV. f. 11.

Sanguinolites cylindricus, Bull. U. S. G. S. 153: 538.

Original description. "Shell small, equivalve; length equal to two and a half times its height; beak about one-seventh the length from the anterior end, elevated above the hinge-line, flattened and enrolled; greatest height along the perpendicular from beak to base; dorsal margin extended, slightly concave upwards and inwards, sharply inflected inwards, forming a long, deep posterior escutcheon or cartilage base; ventral margin nearly straight, curving rapidly from a point opposite the beaks to the anterior extermity, which is abruptly rounded into the deep heart-shaped lunette; posterior extremity truncated by a line extending from the basal to the dorsal margin, and making with the latter an angle of 120°. Valves very ventricose, the greatest thickness being behind the central point on the sharp, prominent umbonal plication, which extends from the beak to the postero-basal angle — the area between this plication and the anterior region being curved subcylindrically from a dorsal to a ventral direction, and the area between the plication and the hinge-line being a triangular, twisted, somewhat concave surface, faintly marked by lines diverging from the beak to the posterior boundary. Entire surface covered with fine irregular striae parallel with the basal and anal margins."

Length of the type specimen $16\frac{1}{2}$ mm., height 7 mm., convexity of one valve 3 mm.

SPATHELLA PHASELIA (Win.).

Pl. XV. f. 10.

Orthonota phaselia, Bull. U. S. G. S. 153: 399.

Shell subelliptical in outline, beaks inconspicuous, nearly terminal, but little elevated above the slightly arcuate hinge-line. Ventral and dorsal margins subparallel, the ventral one sometimes with a slight sinuation in the middle. Posterior margin truncately curved below, broadly rounded above, the most posterior extension of the shell above the middle. Anterior margin rather sharply rounded with a deep lunette above. Shell inflated throughout nearly its entire length, greatest convexity a little in front of the middle. Anterior muscular impression shallow, close to the anterior margin of the shell; posterior impression not recognizable. Surface marked by a few more or less inconspicuous concentric lines of growth.

Length 9 mm., width 5 mm., convexity of a single valve $1\frac{1}{2}$ mm.

Remarks. The specimen here illustrated is the type of the species. Its generic position is uncertain, but it certainly is not *Orthonota*, the genus in which it was originally placed by Winchell. It is here placed with some hesitation in the genus *Spathella*. The species has some resemblance to members of the genus *Modiomorpha*, but is relatively more elongate and narrower posteriorly than the more typical representatives of that genus.

NUCULA IOWENSIS W. & W.

Pl. XV. f. 8–9.

Nucula houghtoni, Bull U. S. G. S. 153: 378.

Original description. "Shell small, subovate or subtriangular in outline, very ventricose. Beaks situated near the posterior (short) end, prominent and incurved. Hinge-plate bent abruptly beneath the beaks; occupied by from five to seven long narrow teeth on the long side and from three to five smaller ones on the short side. Posterior end broadly rounded; anterior end prolonged, obtusely pointed; basal margin strongly arcuate, and the border of the shell thickened."

"Surface characters not determined. This species, like most of the others, occurs in the condition of internal casts, and in some instances the impressions of the exterior surface have not been preserved."

"This shell appears to be subject to considerable variation, at different stations of growth; young specimens often being distinctly triangular, with the posterior end very short, and the basal margin but little arched, while old specimens are subovate in form and the posterior end more prolonged. In one full-grown individual the muscular impressions are very strongly marked, the anterior one being nearly double the size of the posterior, and the basal portion of the shell shows a great degree of thickening."

The dimensions of a rather large specimen are: length 13 mm., breadth 10 mm., and convexity of one valve 4 mm.

Palaeoneilo microdonta (Win.).

Pl. XV. f 15-16.

Nucula microdonta, Bull. U. S. G. S. 153: 387.

Original description. "Shell small, transversely oblong; height equal to two-thirds the length; beaks small, somewhat incurved, but little elevated above the hinge-line, about one-third the length from the short end. Ventral border rapidly curved, and regularly so to the vicinity of the long end, where it is slightly sinuated, from which point a shallow groove extends up nearly to the beak. Dental plates but little angulated between the beaks; the larger bearing near its outer margin 10 or 12 minute transversely tubercular teeth, and the shorter 4 or 5. Teeth not distinguishable to the beaks, but no cartilage pit seems to be present. Anterior muscular pit oblong, surrounded by a large pedal scar. Shell most ventricose in the middle. No surface markings discernible."

Dimensions of the type specimen: length $11\frac{3}{4}$ mm., height 8 mm., convexity of one valve 2 mm.

Remarks. The type specimen which served as the basis for the above original description is the larger one of the two specimens illustrated on the accompanying plate. It is the largest specimen of the species which has been observed, but associated with it are other smaller ones which seem to belong to the same species, and which differ chiefly in having the shell less constricted posteriorly. The species was originally referred to the genus *Nucula*, but it seems better to transfer it to *Palaeoneilo*. It is closely allied to *P. constricta* of the New York Hamilton fauna. It is also allied to the species from the Vermicular sandstone of Northview, Missouri,* which was provisionally identified as *P. constricta*, and to *P. bedfordensis* from the Bedford shale of Ohio.

PALAEONEILO BARRISI (W. & W.).

Pl. XV. f. 17-18.

Palaeoneilo sulcatina, Bull. U. S. G. S. 153: 407.

Original description. "Shell elongate elliptical in outline; the length twice as great as the breadth; valves very ventricose, most gibbous near the anterior end. Beaks of medium size, situated about two-fifths of the entire length from the anterior extremity; incurved, not prominent. Hinge-line gently arcuate throughout its entire length; occupied by a large number of small, curved teeth. Anterior extremity rounded, longest below the middle; basal margin gently arcuate; posterior extremity obliquely truncate, longest near the hinge line, with a slight emargination below. Umbonal slope slightly prominent, with a gentle depression between it and the cardinal line."

"Surface marked by fine, closely arranged, equidistant, concentric lines, which are distinctly undulated as they cross the umbonal slope and the depression above it. Many of the internal casts preserve faint impressions of the concentric lines, except near the basal margin, where they are obscured by the thickening of the shell."

* Trans. Acad. Sci. St. Louis. 9: 32.

The dimensions of an average specimen are: length 17 mm., breadth 8 mm., and convexity of one valve $3\frac{1}{2}$ mm.

LEDA SACCATA (Win.).

Pl. XV. f. 20.

Nuculana saccata, Bull. U. S. G. S. 153: 382.

Original description. "Shell very small, transversely elongate, rostrate at the longer extremity; obtuse, ventricose and saccate at the other. Beak abruptly, though moderately, drawn out, and but slightly incurved. Ventral side strongly curved, becoming nearly straight toward the rostral extremity. Dorsal region deeply excavated for an escutcheon on the longer side of the beak; hinge plates bearing each six or seven teeth; greatest thickness of shell between the beaks and the middle. Pit of adductor of short end very deep on its superior border; the other pit smaller, deepest on its superior border. Surface with fine, indistinct striae of growth.

Length of an average specimen $7\frac{1}{2}$ mm. and width 4 mm.

DEXIOBIA OVATA (Hall).

Pl. XV. f. 1-2.

Original description of Dexiobia whitei. "Shell subrotund, with a slight anterior obliquity caused by a moderate protrusion of the antero-ventral border, from which, in the right valve, a slight elevation extends to the beak; anterior margin rather straight above. Hinge-line short, regularly curved; beaks nearly central. Surface marked by fine radiating ribs — becoming obsolete toward the umbo — and numerous irregular concentric wrinkles, which are generally more conspicuous in the left valve."

The dimensions of a large specimen are, height 38 mm., length 36 mm., convexity of right valve 14 mm.

Remarks. This species was originally described by Hall * as *Cardiomorpha ovata.* The reference of the species to the genus *Cardiomorpha* was erroneous, and Winchell used it as the type of his genus *Dexiobia*, changing the specific name to *whitei.* This change of the specific name, however, does not seem to be warranted. The specimens

* Rep. Geol. Surv. Iowa. 1^2 : 522.

commonly collected are right valves, the left valve being rarely met with. The two valves are quite unlike, and the left one, being less convex and having a less prominent umbo, was described by White * as a distinct species. One specimen in the White collection shows the two valves conjoined, and although it is an imperfect distorted specimen it shows, as has been pointed out by Winchell,† the relationship of these two supposed species. The specimen illustrated is one of those used by Winchell in his description of the genus *Dexiobia*.

DEXIOBIA HALLI Win.

Pl. XV. f. 3-4.

Original description. "Shell small, semi-elliptic; subequilateral. Hinge line straight, extended; in some specimens as long as the greatest width of the shell. Right valve extremely ventricose, flattened and subalate toward the hinge extremities; left valve with a very small obtuse beak, and slender posterior cartilage plate bearing a longitudinal median furrow. Surface smooth."

The dimensions of the most perfectly preserved of the type specimens, a right valve, are, height 17 mm., length 19 mm., and convexity 9 mm.

Remarks. This species and *D. whitei* were considered by Winchell as the types of his genus *Dexiobia*. *D. halli* can always be recognized by its smooth surface and its extended hinge-line. Like *D. whitei* its right valve is most commonly preserved, the left valve being rarely found.

SCHIZODUS TRIGONALIS (Win.).

Pl. XV. f. 21-22.

Cardiomorpha trigonalis, Bull. U. S. G. S. 153: 169.

Original description. "Shell of moderate size, triangular, rather ventricose, with elevated, incurved beaks. Ventral margin slightly convex anteriorly, slightly sinuate near the posterior angle; anterior angle regularly rounded to the subtruncate anterior side; posterior angle rather acute, formed by

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* Proc. Bos. Soc. Nat. Hist. 9: 31.

† Proc. Acad. Nat. Sci. Phil. **1863**: 11.

the termination of the sharp postumbonal ridge, from which the surface descends precipitously to the truncate posterior margin. Hinge-line short, rounded, edentulous. Greatest thickness a little above the middle of the shell. Surface marked only by faint incremental striae."

Length of the type specimen 21 mm., height $7\frac{1}{2}$ mm., and convexity of right valve 6 mm.

Remarks. In the University of Michigan collection, two distinct species of shells have been associated as the types of *S. trigonalis.* The authentic type, judging from Winchell's description, and the measurements given by him, is the larger specimen of the two accompanying illustrations. The other specimens attached to the same card with this one in the Michigan collection, are much smaller and are from the Chonopectus sandstone rather than from the bed under discussion. In a former contribution these Chonopectus sandstone specimens have been described as a new species, *Schizodus iowensis.**

PROMACRUS CUNEATUS Hall.

Trans. Acad. Sci. St. Louis. **10**: 104. *pl. IV. f. 20.*

Original description. "Shell below the medium size, elongate, attenuate, subcuneate anterior to the beak.

"The specimen is a fragment, preserving the anterior end and the beak. It proves, upon comparison with *Promacrus Missouriensis*, to belong to the same genus. It is distinguished by its smaller size, stronger and more regular concentric undulations, and distinct continuous radii of the surface, which become nodose at their intersections with the concentric undulations.

"The specimen, anterior to the beak, has a length of 45 mm. and a height at the beak of 24 mm."

Remarks. The horizon of this species, as cited by Hall, is simply "Yellow Sandstones at Burlington, Iowa." At the time of publication of the description of the Chonopectus sandstone fauna, no specimen of this species had been observed and it was provisionally included in that fauna and a copy of Hall's original illustration was reproduced. Since

* Trans. Acad. Sci. St. Louis. **10**: 101.

that time, through the courtesy of Dr. E. O. Hovey, the writer has been able to examine the type specimen of the species in the collections of the American Museum of Natural History, and it proves to be a member of the upper yellow sandstone fauna at Burlington, and not of the Chonopectus sandstone. A much more perfect specimen than the type, from Northview, Missouri, has been illustrated in these Kinderhook Faunal Studies. I.*

GASTEROPODA.

STRAPAROLLUS ANGULARIS Weller.

Pl. XV. f. 26-27.

A single specimen of an internal cast, in this fauna, seems to be identical with the species described from the Chonopectus sandstone as *Straparollus angularis*,† it being one of the very few species which are common to the two faunas.

STRAPAROLLUS sp. undet.

Pl. XV. f. 25.

A single cast of a small specimen of this undetermined species of Straparollus has been observed. Only the upper surface of the shell is exposed upon a slab, and this surface exhibits a slight, regular convexity. About three whorls in all are preserved.

BUCANOPSIS PERELEGANS (W. & W.).

Pl. XV. f. 23-24.

Bellerophon perelegans, Bull. U. S. G. S. 153 : 144.

Original description. "Shell small, subglobose; umbilicus small, aperture transverse, reniform. Back and sides marked by fine, sharply elevated revolving lines, which are about equal to the spaces between them, finer and more closely arranged in the middle than on the sides of the shell. Dorsum marked by a narrow, elevated, revolving band; bounded on each side by a shallow depression. The revolving lines on the band are much finer than those on the body of the shell. Very fine transverse striae of growth across the

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* Trans. Acad. Sci. St. Louis. **9** : 35. *pl. III. f. 2.*

† Trans Acad. Sci. St. Louis. **10** : 110.

revolving striae, give a finely cancellated appearance to the surface. Margin of the peristome nearly straight, or with a gentle backward curvature to the shallow central notch.''

Remarks. The specimen of this species here illustrated, is the largest one of the types, being nearly twice as large as the average representatives of the species. On the internal casts the delicate surface markings cannot be recognized, but they are beautifully shown in the external impressions of the shell. On the casts the only surface irregularities usually recognizable, are the revolving dorsal band and some faint, irregular, concentric wrinkles of growth.

Among the specimens indicated as types of this species in the University of Michigan collection, three distinct species are represented. A number of the specimens are good examples of *Bellerophon bilabiatus*, and another has been made the type of a new species, *Bucanopsis deflectus*.* The specimens which are retained as the types of the species are those which apparently were used as a basis for the original description, and were found in the fauna under consideration.

BELLEROPHON sp. undet.

Pl. XV. f. 28.

This undetermined species is represented in the collections which have been studied, by a single very imperfect specimen which is here illustrated. The species is much larger than *B. perelegans*, and when perfect examples are found, it may prove to be an undescribed species.

PHANEROTINUS PARADOXUS Win.

Trans. Acad. Sci. St. Louis. **10:** 112. *pl. VIII. f. 1.*

The types of this species are wax casts from a natural mould which probably has been lost. They are said to be from the "yellow sandstone" at Burlington, but as no other specimens have been seen, it is impossible to determine certainly from which yellow sandstone horizon the types were secured. The species was included provisionally in the Chonopectus fauna, but in view of the fact that the same species occurs in the vermicular sandstone at Northview, Missouri,†

* Trans. Acad. Sci. St. Louis. **10:** 114.

† Trans. Acad. Sci. St. Louis. **9:** 43. *pl. V. f. 6.*

associated with so many species which ally that fauna with the upper yellow sandstone fauna at Burlington, with none at all which suggest the Chonopectus fauna, it seems more probable that *Phanerotinus paradoxus* is from the upper yellow sandstone fauna and not from the Chonopectus fauna.

DENTALIUM GRANDAEVUM Win.

Pl. XV. f. 29.

The types of this species preserved in the White collection are from both the Chonopectus sandstone and the upper yellow sandstone, and the specimens from the two horizons seem to be identical as far as external appearances go.

IV. THE FAUNA OF BED NO. 6.

COELENTERATA.

CORALS.

ZAPHRENTIS sp. undet.

Several specimens of corals which are apparently members of the genus Zaphrentis, are present in the fauna of the oolitic limestone at Burlington. It is possible that two species may be represented, one perfectly straight and the other one curved. Additional material and a study of the internal structure of these corals will be necessary before they can be successfully determined.

MOLLUSCOIDEA.

BRACHIOPODA.

LEPTAENA RHOMBOIDALIS (Wilck.).

Pl. XVI. f. 7–8.

This species occurs, but not abundantly, in the oolite fauna. The individuals examined do not differ essentially from the ordinary form of this cosmopolitan species.

Orthothetes inflatus (W. & W.).

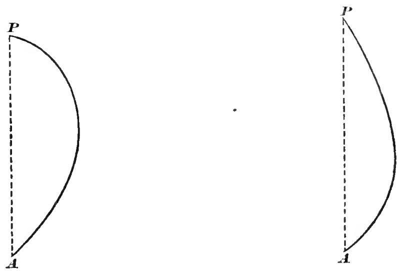
Pl. XVI. f. 2-3.

The types of this species are from both the oolite bed and the base of the superjacent brown magnesian limestone. The most perfect specimen among the types is from the upper bed, and a description of the species is given with the description of the fauna from that horizon (see p. 195), although the species is probably more common in the oolite.

Orthothetes sp. undet.

Pl. XVI. f. 1.

Associated with *O. inflatus* in the oolite bed there is another form of the genus *Orthothetes* which may prove to be a distinct species. It differs from *O. inflatus* in having the greatest convexity of the brachial valve much nearer the front (A) of the shell, as is shown in the accompanying profile outlines.



Specimens of this form are often larger than the typical *O. inflatus*, but not sufficient material has been in hand for study to determine whether or not the larger size of the adult shells is a constant characteristic. No pedicle valves, which can be definitely correlated with this type of brachial valve, have been observed.

Rhipidomella burlingtonensis (Hall).

Pl. XVI. f. 6.

The specimens in the oolite bed which have been identified with this species, differ from the normal form of the species on account of their much smaller size, as is shown in the illustration, and on account of the greater flattening of the pedicle valve along its median portion toward the front of the shell. In some respects the shell resembles *R. dubia* of the Spergen Hill fauna, but its hinge-line is longer than in that species.

SCHIZOPHORIA SUBELLIPTICA (W. & W.).

Pl. XVI. f. 4–5.

Rhipidomella subelliptica, Bull. U. S. G. S. 153 : 525.

Original description. "Shell medium size, subelliptical in outline. Hinge line about two-thirds or three-fourths as long as the greatest breadth of the shell. Cardinal extremities rounded, valves subequal, moderately convex; the pedicle somewhat flattened toward the front, very ventricose on the umbo; beak small and pointed; area about one-third as high as long, delthyrium twice as high as wide. Brachial valve more regularly convex than the pedicle, and the beaks less elevated, very small and pointed, but little incurved."

"Surface marked by fine, equal rounded striae, which are curved upwards near the extremities of the hinge-line, and some of them run out on the cardinal border. Increased both by bifurcation and implantation."

Dimensions of an average specimen from the oolite bed: length 10 mm., breadth 12 mm, and convexity of both valves 5 mm.

Remarks. This little shell is a common species in the oolitic bed, and also occurs in the base of the superjacent magnesian limestone. One specimen from this latter horizon, included among the types of the species in the University of Michigan collection, is much larger than any specimen from the oolite, its length being 18 mm., and its breadth 23 mm.

This species has been referred by Schuchert * to the genus *Rhipidomella*, but it should rather be referred to *Schizophoria*. The brachial valve has all the appearance of a diminutive *S. swallovi*, but the pedicle valve has a higher area and a relatively much more prominent umbo than that species.

CHONETES LOGANI N. & P.

Pl. XVI. f. 10–11.

Original description. "Shell small; transverse, having its greatest breadth near the cardinal border. Pedicle valve

* Bull. U. S. G. S. 87 : 352.

inflated, without a sinus, covered with about thirty rugose ribs. Ears small, scarcely separated from the body of the shell. Beak rather large and recurved. Ribs flattened and crossed by fine lines, many of them dichotomous. Area and brachial valve unknown. Traces of tubes can be seen on the cardinal edge, but the number cannot be ascertained. Length 6 mm.; breadth 9 mm.

Remarks. This species has always been the cause of much confusion. Only a few years after its first description by Norwood and Pratten, Hall * identified a common species from the Burlington limestone as *C. logani*, which he described as having from 100 to 125 dichotomizing striae, while the original *C. logani* was said to have but about 30. Worthen † first detected Hall's error and gave the name *C. illinoisensis* to the Burlington limestone species. At the time of publication of volume IV of the New York Paleontology, Hall ‡ seems to have recognized the true *C. logani* from Burlington. The latest reference to the species has been made by Girty, § who has described it from the Madison limestone of the Yellowstone Park, referring it to Shumard's species *C. ornatus*, although the identity of the species with *C. logani* is suggested. The specimen illustrated by him is as typical *C. logani* as any that can be found at Burlington.

At Burlington this species seems to be restricted to the oolitic limestone bed No. 6. It can always be recognized by its rather coarse plications and by its concentric markings which are stronger on the ribs than in the depressions. The shell is also more convex than any of its associates, and the fullness extends well out towards the cardinal extremities so that the auriculations of the shell are not so conspicuous as they are in some members of the genus. The shell often attains a greater size than the dimensions given by Norwood and Pratten, the larger ones being $8\frac{1}{2}$ mm. long and 10 mm. wide. The larger shells are more convex than the smaller

* Rep. Geol. Surv. Ia. 1^2: 598.

† Trans. Acad. Sci. St. Louis. **1**: 571.

‡ Pal. N. Y. **4**: 137.

§ Monog. U. S. G. S. 32: 527.

ones and the hinge-line is relatively shorter. Usually two spine bases can be detected on the cardinal margin each side of the beak, and sometimes a third one. The spines themselves are oblique in position. On the larger shells the number of plications sometimes reaches forty.

CHONETES BURLINGTONENSIS n. sp.

Pl. XVI. f. 9.

Shell of medium size, semielliptical in outline, the hinge-line as long as or a little shorter than the greatest width of the shell. Pedicle valve prominent on the umbo, compressed towards the cardinal angles, and flattened or slightly sinuate along the median line. The bases of two oblique spines on the cardinal margin may usually be seen on each side of the beak. Surface of the pedicle valve ornamented with about 100 rounded plications on the margins of the shell, which originate by bifurcation from less than 25 at the beak, and which are furnished with numerous tubular openings. The furrows between the plications are narrower than the plications themselves. Besides the plications the shell is marked by exceedingly fine, inconspicuous concentric striae, which are strongest in the radiating furrows. Brachial valve unknown.

The dimensions of an average sized specimen are: length 9 mm., breadth 14 mm., and convexity 3 mm.

Remarks. This species is less common in the oolite fauna than *C. logani*, from which it can be easily distinguished by its larger size, its greater number of plications, its less convexity, its more compressed cardinal angles, and by the absence of the conspicuous concentric striae. In size and general outline the species resembles *C. illinoisensis*, but it differs from this common species of the Burlington limestone in its smaller number of plications and in its smaller number of cardinal spines.

PRODUCTELLA CONCENTRICA (Hall).

Pl. XVI. f. 12–14.

*Original description.** "Shell small, semi-elliptical; hinge-line scarcely so long as the greatest width of the shell.

* This is the description published by Hall in 1858 in Rep. Geol. Surv. Ia. 1[2]: 517. An earlier description was published in 1857 by the same author in the Reg. Rep. of N. Y. State Mus. Nat. Hist.

Brachial valve deeply concave, abruptly curved and almost geniculate in front; cardinal extremities slightly contracted; upper half of shell marked by strong concentric wrinkles and somewhat distant spiniform tubercles; lower half of shell marked by elongate spiniferous ridges."

Remarks. This species was originally described from the "sandstone of the age of the Chemung group" at Burlington, but it seems to be most abundant in the oolitic limestone bed, all the specimens which have been studied being from that horizon. When the original description was published, the pedicle valve was said to be unknown, but an associated pedicle valve was described and illustrated as *Productus shumardianus.* Clarksville, Missouri, and Burlington, Iowa, were recorded as the localities for this latter species, but the Burlington specimens should without doubt be included in the *P. concentricus.*

The pedicle valve is gibbous in the middle and compressed at the cardinal extremities, it is flattened along the median line, but with no sinus. The ornamentation is like that of the brachial valve. An average sized specimen is 16 mm. in length, 18 mm. in breadth, with the convexity of the pedicle valve 9 mm.

Some of the specimens which have been studied, and which are evidently members of the same species, are marked by much more numerous spine bases than those which have been illustrated.

The species was originally described as a member of the genus *Productus*, but Schuchert has transferred it to *Productella.* The essential features of the hinge which characterize the genus *Productella* have not been observed in any of the Burlington specimens, but in the character of its surface ornamentation the species is more like members of the genus *Productella* than like typical members of the genus *Productus.*

PRODUCTUS ARCUATUS Hall.

Pl. XVI. f. 15.

Original description. "Pedicle valve much elevated, longer than wide, very gibbous, extremely arcuate, the beak recurved upon itself so that the hinge is nearly opposite the center of the back of the shell; hinge-line shorter than the width of the shell: cardinal extremities produced into small angular ears."

"Surface marked by strong radiating costae which bifurcate upon the umbo and below, and sometimes coalesce towards the base of the shell, entire surface covered by fine undulating concentric striae, and, in the upper part, by a few strong wrinkles which are conspicuous on the ears and umbo. A few marks of the bases of spines are noticed, but they appear to have been irregularly distributed, and in our specimen do not appear at all. Dorsal valve and interior unknown."

Dimensions of an average example: length 19 mm., breadth 19 mm., and convexity of pedicle valve 15 mm.

Remarks. This species has been variously placed at different times in the genera *Productus* and *Productella*, but there seem to be no grounds for removing it from the first of these genera. It is a well defined *Productus* of the *semireticulatus* type. It resembles *P. burlingtonensis* H., but is always a smaller shell and never has any indication of a median sinus. The brachial valve is flattened toward the cardinal extremities, and gently concave in the posterior median portion, but bends upward rather abruptly toward the lateral and anterior margins.

ATHYRIS CRASSICARDINALIS White.

Pl. XVI. f. 18-24.

Shell small, breadth a little greater than the length, the greatest breadth posterior to the middle, more or less broadly pointed posteriorly. Pedicle valve most convex, the greatest convexity posterior to the middle, elevated along the median line; the delthyrium large, open in all the specimens observed; the hinge-teeth large and strong, pointing obliquely inward and toward the brachial valve. Brachial valve flattened transversely, more or less strongly arched longitudinally; the umbo rather prominent, with the shell flattened on each side; the cardinal process notched in front, large and platform-like, slightly excavated on top. Surface of shell marked by several more or less conspicuous growth lines which are usually strongest on the pedicle valve.

The dimensions of a rather large individual are: length of brachial valve 10 mm., and width of brachial valve 10½ mm. The corresponding pedicle valve would, of course, have a little greater length with the same width.

Remarks. As indicated by the types in the University of Michigan collection, two quite distinct shells were included by White in his species *Athyris crassicardinalis*. The original description applies in the main to the commoner one of these two shells which has been described above, and the specific name is therefore retained for this species, but the generic relations of the shell are extremely doubtful. It is almost certainly not a member of the genus *Athyris*, but as no better disposition can be made of it at the present time, it is allowed so to remain until its real generic relationships can be determined.

Because of its deep muscular impression and consequent thinness of the shell, the pedicle valve of this species is perfectly preserved less often than the brachial valve. The most characteristic features of the shell are, the peculiar transverse flattening of the brachial valve, the large cardinal process and the posterior position of the maximum breadth of the shell.

The other shell which was included in this species by White, is a small member of the genus *Cleiothyris* which will have to be considered separately.

CLEIOTHYRIS HIRSUTA Hall.

Pl. XVI. f. 25-27.

Shell subcircular in outline, lenticular, the two valves being subequally convex. Pedicle valve most convex towards the beak, the beak incurved so as to bring the foramen nearly in line with the margin of the shell. Brachial valve regularly convex, its beak closely incurved beneath the beak of the opposite valve. Fold and sinus usually absent, but in some specimens there is a faint sinus in the pedicle valve with a corresponding fold in the brachial valve. Surface of entire shell marked by fine, concentric, lamellose lines of growth, which give origin to successive rows of minute spines. Length of an average specimen 9 mm., width 10 mm., and thickness 6 mm.

Remarks. Among the specimens used by White for the description of *Athyris crassicardinalis*, three distinct species belonging to there different genera were included. Eleven out of the sixteen type specimens are members of a species characterized by a peculiar transversely flattened brachial valve and which shows no indication of the concentric rows of spines mentioned in the original description as being present in some specimens. These nine specimens have been retained as the typical form of *Athyris crassicardinalis*. One of the five additional specimens is a member of the species *Nucleospira barrisi*, and four remaining specimens seem to be identical with *Cleiothyris hirsuta*, first described from the Spergen Hill fauna in Indiana, of St. Louis age. It is upon these specimens alone that the fringes mentioned by White are sometimes preserved. These specimens from the Kinderhook oolite at Burlington, are so nearly like many of those from St. Louis oolite of Indiana, both in size, form and manner of preservation, that were specimens from the two localities mixed together it would be impossible to distinguish them. It is quite possible that all these shells, along with other somewhat larger ones from the Osage faunas, should be considered as being but variations of *Cleiothyris roissyi*.

SPIRIFER MARIONENSIS Shum.

Pl. XVI. f 16-17.

Shell subcircular or subsemielliptical in outline, from one-half to two-thirds as long as broad, the valves subequally convex, the cardinal extremities usually mucronate in the younger individuals, but becoming less pointed in the older specimens. Pedicle valve with the greatest convexity posterior to the middle, umbo prominent, beak pointed and incurved; the sinus well defined, narrow and angular at the beak, becoming broad, shallow and less well defined toward the front, marked by three or four dichotomizing plications; cardinal area of moderate height, the sides subparallel, the delthyrium rather broadly triangular. Brachial valve regularly convex, flattened toward the cardinal extremities; the mesial fold scarcely elevated above the general surface of the valve, marked by dichotomizing plications which are from four to six in number at the front margin. Surface of each valve marked by from fifteen to twenty-five plications on each side of the fold and sinus, all of which are often simple but with the first one or two adjacent to the fold and sinus sometimes divided. Entire surface also covered by concentric lines of growth which are lamellose on perfectly preserved shells.

Remarks. The most typical form of this somewhat variable species is that which occurs in the Louisiana limestone of Pike and Marion counties, Missouri. The specimens from the oolitic limestone at Burlington are usually somewhat smaller than the largest individuals from the Louisiana limestone, and the beak of the pedicle valve is less incurved. In all other respects, however, examples from the two localities are identical, and it seems impossible to consider them in any other light than as members of a single species.

Dielasma allei (Win.).

For a full description with illustrations of this shell, the reader is referred to page 162 of the present paper. The types of the species are from both the upper yellow sandstone and the oolite bed at Burlington. The single specimen from the oolite bed is but a fragment of one valve, but it is probably the same species as the more perfect specimen from the yellow sandstone below. The description of the shell structure given by Winchell, was drawn wholly from this oolite specimen.

MOLLUSCA.

PELECYPODA.

Pernopecten cooperensis (Shumard).

Pl. XVII. f. 1.

This species has already been fully described and discussed in these studies.* The specimens in the oolite bed are typical of the species described by Hall from this same locality as

* Trans. Acad. Sci. St. Louis. 9 : 24.

Avicula circulus,* but his name must be considered as a synonym of *Pernopecten cooperensis*. The oolite specimens are usually larger than those from the subjacent yellow sandstone, but are about the same size as those usually found in the Vermicular sandstone fauna at Northview, Missouri.†

CONOCARDIUM PULCHELLUM W. & W.

Pl. XVII. f. 2–3.

Original description. "Shell small, general form triangular, with ventricose valves. Hinge line straight, the length equal to that of the posterior slope. Anterior end cuneate; posterior end obliquely truncate. Basal line gently arcuate, widely gaping near the anterior extremity; hiatus elongate ovate, distinctly crenate on the inner border. Beaks minute, incurved, situated posteriorly; umbonal slope rounded, posterior space concave; siphonal tube small. Entire surface marked by distinct, diverging radii, those of the posterior space a trifle finer than those of the body of the shell; also by very fine concentric striae."

The dimensions of the type specimens are: length along hinge line 7 mm., greatest height 6 mm., thickness of both valves 5 mm.

Remarks. This little species is strongly suggestive of some of the small species of *Conocardium* which occur in the Spergen Hill fauna in Indiana at the horizon of the St. Louis limestone. The resemblance is even more striking because of the similarity of the lithologic characters of the beds containing the fossils at the two localities, both formations being white oolitic limestone. The Burlington species, however, is distinct from any of those in the Spergen Hill fauna, its greatest resemblance being with *C. meekanum*.

GASTEROPODA.

LOXONEMA sp. undet.

Pl. XVII. f. 9.

The interior casts of a species of *Loxonema* are not uncommon in the oolite bed, but no specimens preserving the shell

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* Rep. Geol. Surv. Ia. **1**^{2}**:** 522. The original *A. circulus* Shum., is distinct.

† Trans. Acad. Sci. St. Louis. **9 :** 24.

and the external markings, have been observed. The specimen illustrated is a good example of the species. In the University of Michigan collection this specimen is designated as one of the types of *Murchisonia quadricincta* Win., but is probably not even cogeneric with this species.

PLEUROTOMARIA ? QUINQUESULCATA Win.

Pl. XVII. f. 10–11.

Original description. "Shell of medium size, depressed conical, consisting of three or four rapidly enlarging whorls. Outer whorl nearly as wide as all the others, having a nearly circular section, and presenting on its exterior about five longitudinal furrows, covering the space from the suture above to the base below; shell otherwise apparently smooth."

"Diameter of last whorl 27 mm.; height of spire about 18 mm."

Remarks. The specimen here illustrated is believed to be the type of the species although it is not so marked. It is the only specimen so labeled in the University of Michigan collection, and agrees exactly with the measurements given by Winchell. The specimen is a very imperfect one, and it is impossible to determine its generic relations. The revolving furrows mentioned by Winchell seem to be wholly imaginary.

PLEUROTOMARIA ? sp. undet.

Pl. XVII. f. 12.

A single specimen of a small coiled shell with a low spire, has been observed. Its generic relations cannot be determined and so it is only referred provisionally to the genus *Pleurotomaria*.

STRAPAROLLUS OBTUSUS (Hall).

Pl. XVII. f. 6–8.

Original description. "Shell discoid, planorbiform. Spire little elevated, consisting of five or six volutions which increase in size very gradually from the apex; largest outer volution very obtusely angular on the upper side towards the outer margin, and below this somewhat flattened to the periphery of the shell below, where it is very regularly and symmetrically rounded; upper side, from the obtuse angle to the suture, flat on the inner volutions, and slightly sloping inward on the outer volutions; aperture straight above, circular below.

"Surface marked by fine, closely arranged striae of growth."

Remarks. This species is rather a common one in the oolite bed at Burlington, and exhibits some variations in its characters which are not mentioned in the original definition. The chief of these is in the elevation of the spire, it being slightly elevated in some specimens while in others it is slightly depressed below the plane of the outer volution. The angular character of the upper side of the volutions is oftentimes more or less obscure, the cross section of the volutions being almost circular. The umbilicus is broad and in it all the volutions of the shell are exhibited. The specimen here illustrated is perhaps a little smaller than the average adult size, the shell sometimes attaining a diameter of 45 mm.

STROPHOSTYLUS BIVOLVE. (W. & W.).

Pl. XVII. f. 4-5.

Original description. "Shell small, ventricose, composed of about two closely coiled, rounded volutions, spire not elevated above the surface of the outer volutions. Inner whor minute, outer volution more rapidly expanding and ventricose. Section of the volution transversely ovate, narrowest at the inner or ventral margin; border of the aperture with a shallow sinus on the upper side, and another below the middle. Surface marked by fine transverse striae, parallel to the border of the aperture."

Greatest diameter of the type specimen, 20 mm., greatest width of the outer volution of the same specimen 14 mm., height of aperture 11 mm.

Remarks. The specimens of this species labeled "types" in the University of Michigan collection, are five in number, two of them being from the Chonopectus sandstone and three from the oolitic limestone. One of the Chonopectus sandstone specimens is not even cogeneric with the other individuals and may be a specimen of *Naticopsis depressus* Win., the other one* is a member of the genus *Strophostylus*, but is probably specifically distinct from the specimens from the oolitic layer. These last mentioned specimens should be considered as the true types of the species. They are three in number, the largest one is illustrated here for the first time, and one of the others, the most perfect of all, has been well illustrated by Keyes.† The third specimen is smaller than either of the others and shows no characters which are not better exhibited on the others. The Chonopectus sandstone specimen which is a true *Strophostylus* differs from the oolitic specimens in having the inner whorl of the shell much thicker so that the shell expands much less rapidly; the number of whorls also in this individual is probably greater than in the oolite specimens although the apex of the shell is destroyed.

CEPHALOPODA.

Orthoceras indianense Hall.

Pl. XVII. f. 13–14.

A small, smooth orthocereas which has usually been referred to this species is not uncommon in the oolite fauna. The specimens are usually elliptical in cross-section with the siphuncle situated eccentrically. Specimens from the Chonopectus sandstone,‡ have been referred to the same species, and those from the Vermicular sandstone at Northview, Missouri, which were identified as *C. chemungense* Swallow,§ are also possibly the same.

Gyroceras burlingtonensis Owen.

Pl. XVIII. f. 1.

Original description. "Scroll-shaped; volutions about two, rapidly enlarging; chambers forty-eight (?), indicated by undulating lines curving from the inner margin of the periphery."

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* For an illustration of this specimen see Trans. Ac. Sci. St. Louis. **10.** *pl. V. f. 4–5.*

† Rep. Mo. Geol. Surv. **5.** *pl. 53. f. 4 a–b.*

‡ Trans. Acad. Sci. St. Louis. **10:** 120.

§ Trans. Acad. Sci. St. Louis. **9:** 45.

"This *Gyroceras* is of unusually large dimensions,— about fifteen inches in diameter, and nearly three feet along the dorsal circumference of a single coil. It occurs in the oolitic bed, at the top of member *a*, of the Lower Series of Carboniferous Limestones, under the encrinital beds of the quarries at Burlington, Iowa."

Remarks. This species has not been observed by the writer. In connection with its original description, its stratigraphic position at Burlington was so definitely stated that there can be no doubt of its being a member of the fauna under discussion. A tracing of the outlines of the original drawing is presented on plate XVIII, but according to the dimensions given for the species, this drawing must be less than one-third natural size, although no statement to that effect is made in the explanation of the original plate.

V. THE FAUNA OF BED NO. 7.

COELENTERATA.

LEPTOPORA TYPA Win.

Pl. XX. f. 19.

Original description. "Polypary subcircular in outline, and slightly convex on the general surface; composed (in the specimens examined) of about 25–30 rather large cells of which the internal ones are hexagonal, and the peripheral rounded exteriorly; margins of cups strongly elevated; radial lamellae about 20."

"Diameter of mass 18 mm., diameter of cells about $3\frac{1}{2}$ mm., and their depth about $1\frac{1}{2}$ mm."

Remarks. The type specimens of this species in the University of Michigan collection are two in number, one being a cast of the surface of a corallum and another less perfect colony shows several corallites in which the substance of the coral has been preserved. The specimen here illustrated is the cast and in it the bounding rims of the corallites are of course represented by grooves instead of elevations. In the specimen retaining the coral substance each corallite is seen to possess a low, broad columella and the septa are almost obsolete, being represented by faint ridges near the sides of the cups.

MOLLUSCOIDEA.

BRACHIOPODA.

ORTHOTHETES INFLATUS (W. & W.).

Pl. XIX. f. 10–12.

Original description. "Shell above a medium size, somewhat semicircular in outline; the hinge usually a little shorter than the greatest width of the shell causing a slight rounding of the cardinal extremities. Pedicle valve concave in the center, and elevated at the beak, which is straight and pointed, directed obliquely backward from the hinge-line, area rather high, irregular in width, and about one-third as high as long; delthyrium very narrow, extending to near the point of the beak, closed to near the base by a thin, rounded deltidium. Brachial valve strongly inflated, very prominent on the umbo, a little flattened at the cardinal extremities.

"Surface marked by moderately strong, rounded, somewhat alternate, radiating striae, which present a wiry appearance. The interior of the brachial valve is characterized by a very large, flabelliform cardinal process, marked by several strong plications."

The dimensions of the type specimen are: length 28 mm., breadth 28 mm., and thickness of the two valves 18 mm.

Remarks. The type specimens of this species are from both the magnesian limestone bed and the subjacent oolite bed. The only specimen which is approximately perfect is from the magnesian limestone and is here illustrated.

ORTHOTHETES INAEQUALIS (Hall). ?

Pl. VIII. f. 9.

Among the specimens of *Orthothetes* from the magnesian limestone bed at Burlington, there are two forms. The less common one is that already described as *O. inflatus*, in which the length and breadth are approximately equal. The most abundant form, however, is one having the breadth considerably in excess of the length as seen in figure 9 of plate XIX, and having the pedicle valve less concave. Several individuals of this form in the University of Michigan collection, the one here illustrated being among them, have been labeled *Streptorhynchus inaequalis* by Winchell, but they do not wholly agree with authentic specimens of *Orthothetes inaequalis* which is typically from the upper yellow sandstone bed beneath the oolite. The type specimens of *O. inflatus* are three in number, and one of them is the brachial valve of an individual of this broad form, so it seems that White and Whitfield considered both forms as variations of a single species, and it is not improbable that they were co rect in this supposition.

PRODUCTUS PUNCTATUS Martin.

Pl. XIX. f. 8.

Typical examples of this well-known carboniferous species occur in the fauna. All the specimens which have been observed are internal casts of the pedicle valve, the specimen illustrated being the largest and most perfect example seen.

SCHIZOPHORIA SUBELLIPTICA (W. & W.).

Pl. XIX. f. 6–7.

The types of this species are from both the magnesian limestone bed and from the subjacent oolite bed although the original description of the species was probably taken primarily from the oolite specimens. One well preserved brachial valve from the magnesian limestone is much larger than any of the oolite specimens but seems to agree with them in all its essential characters.

CAMAROPHORIA CAPUT-TESTUDINIS (White).

Pl. XIX. f. 1–4.

Original description. "Shell large, subtriangular, subcuneate, front rather fully rounded, meeting the lateral slopes at an obtuse angle; sides somewhat concave, free from plications near the beaks, and sloping to them with gentle incurvatures, giving the shell an angular appearance about the beaks, which are small, and at which the sides meet at an acute angle; both valves regularly and nearly equally convex; brachial beak closely incurved beneath the pedicle beak, which is slightly incurved. Foramen and delthyrium unknown. Surface marked by from sixteen to eighteen distinct somewhat rounded plications on each valve, which mostly reach the beak with some distinctness, but are occasionally increased both by implantation and bifurcation. They are traversed by fine radiating lines, and crossed by fine concentric lines of growth."

"Mesial fold and sinus scarcely defined, but the front is slightly emarginate in the older specimens, by the elevation of the lingual extension of the lower pedicle valve with a gradual curve, which includes five or six of the plications."

The dimensions of the type specimen are: length 43 mm., breadth 39 mm., and thickness 27 mm.

Remarks. The geologic horizon of this species is recorded by its original author as "base of the Burlington Limestone," but the specimens indicated as types in the University of Michigan collection include as well individuals from the magnesian layer at the top of the Kinderhook. These lower specimens, however, are all more or less imperfectly preserved, though they apparently belong to the same species as the more perfect Burlington limestone specimens. Among the accompanying illustrations of this species, figures 1, 2 and 3 are views of a nearly perfect individual from the Burlington limestone, which may be taken as the true type of the species. Figure 4 is one of the most perfect of the magnesian limestone specimens. The shell illustrated by Keyes (Mo. Geol. Surv., Vol. V., Paleontology II. pl. 41, Fig. 11), under the name *Rhynchonella sp.?* is quite certainly an individual of this species.

Camarotoechia persinuata (Win.).

Pl. XIX. f. 5.

Rhynchonella persinuata, Bull. U. S. G. S. 153: 534.

Original description. "Shell of medium size, transversely oval, with abbreviated rostral extension. Cardinal slopes nearly straight, sides rounded, front straight. Pedicle valve depressed, with about twenty straight plications, of which eight occupy the broad and rather shallow sinus. Anterior margin of valve abruptly deflected. Dental lamellae extending nearly one-third the length of the valve. The beak of this valve projects nearly in the plane of the shell, and the lateral portions of the valve are continued, without convexity, to the borders, thus giving this valve a peculiarly flattened surface — the broad sinus forming a similar plane lying at a lower level."

The dimensions of the type specimen are: length 17 mm., breadth 27 mm., and convexity of pedicle valve 4 mm.

Remarks. A single specimen of this species has been observed in the University of Michigan collection, and although it is not marked "type" it is undoubtedly the specimen used by Winchell in his description of the species. It is an imperfect specimen, only a cast of the interior of the pedicle valve being preserved. The species is apparently a member of that group of Rhynchonelloid shells for which Hall and Clarke have used the name Camarotoechia, and it is therefore referred to that genus. It is closely allied to, and is perhaps not specifically distinct from the English species *Rhynchonella pleurodon* Phill., and from an examination of the illustrations of that species given by Davidson, it seems probable that that author would not have considered the American specimen as a distinct species. The species described from the Chouteau limestone of Cooper County, Missouri, as *R. cooperensis* Shum. is perhaps not distinct from this Burlington species.

SPIRIFER PECULIARIS Shum. ?

Pl. XX. f. 1.

A single specimen which may belong to this species has been observed in the fauna under consideration. It is larger than the specimens in bed No. 5 which have been referred to this species, and is also larger than specimens of the species from central Missouri. The specimen also differs from authentic representations of *S. peculiaris* in having a well defined cardinal area. This last difference, however, may be due to the state of preservation.

SPIRIFERINA SOLIDIROSTRIS (White).

Pl. XX. f. 2–4.

Original description. "Shell rather small, nearly semicircular, wider than long, widest at the hinge-line, where it is sometimes extended into submucronate points, rounded in front.

"Brachial valve more convex from beak to front than transversely. Beak scarcely prominent, slightly projecting beyond the hinge-line.

"Pedicle valve about twice as deep as the opposite one, regularly arcuate from beak to front, but a little depressed near the cardinal extremities. Area large and well defined, delthyrium narrow, beak acute, incurved, and becoming solidified as the delthyrium is progressively closed. Dental plates strong, projecting a little forward of the hinge-line. From six to eight prominent plications on each side of the mesial fold and sinus, which decrease regularly in size toward the hinge extremities. Sinus rather broad and deep, distinctly defined even to the point of the beak; a slightly elevated ridge extends along its bottom, and a corresponding depression along the mesial fold.

"Mesial fold prominent and widely separated from the plications. Surface marked by fine, lamellose, concentric striae, which arch upon the plications and the ridge in the mesial sinus, and doubly arch upon the mesial fold."

The dimensions of one of the best preserved pedicle valves among the types are: length 11½ mm., width along the hinge-line 15 mm., and convexity 6 mm. Another brachial valve is 9½ mm. long, 19 mm. wide along the hinge-line, and has a convexity of 4 mm.

Remarks. Neither the types nor any authentic specimens of this species have ever been illustrated, and it has often been confused with *S. subtexta*, a species described by White from the base of the Burlington limestone. This latter species also has never been illustrated, and therefore a figure of the type specimen has been introduced on the plate with *S. solidirostris* (see Plate XX, fig. 5–6). *S. solidirostris* may be recognized by its stronger lamellose lines of growth, and by the slight furrow in the median fold and the corresponding elevation in the sinus.

NUCLEOSPIRA BARRISI White.

Pl. XX. f. 7–11.

Original description. "Shell transversely oval, gibbous, becoming ventricose with age. Hinge-line short, surface traversed by a few imbricating lines of growth, which increase in number near the border in the older specimens. Pedicle valve with a narrow, faintly impressed sinus extending from the beak along the shell, corresponding to the inner septum, which gradually expands into a broader and deeper depression, and, with a corresponding elevation in the opposite valve at the margin, gives it a considerable sinuosity in front. Beak short, acute, and slightly incurved. A minute round foramen just beneath the apex. False area small, concave. Longitudinal septum not extending beneath the beak, but ending about even with the cardinal teeth. Brachial valve more gibbous than the pedicle, umbo prominent, longitudinal septum extending the full length of the shell, but becoming indistinct at the front margin. A narrow, scarcely perceptible impression extends along the back, opposite the septum. The spatulate portion of the cardinal process short, and bending slightly upward, to correspond to the under side of the concave area, beneath which it passes at nearly a right angle to the basal portion. The crura, being very small, serve to give sharpness to the angle, and also, by slight lateral projection in front of the cardinal teeth, give security to the hinge. Length of shell from 8 mm. to 10 mm., breadth from 10 mm. to 12 mm."

MOLLUSCA.

GASTEROPODA.

WORTHENIA MISSISSIPPIENSIS (W. and W.).

Pl. XX. f. 12.

Pleurotomaria mississippiensis, Bull. U. S. G. S. 153: 457.

Original description. "Shell rather above a medium size, spire elevated, composed of five or six volutions; the height a little greater than the diameter of the base. Volutions flattened on the upper side, the plane extending from the suture to the middle of the whorl, regularly rounded on the inner side. Periphery marked by a revolving band, which on the outer volution is an eighth of an inch in breadth, prominent at the margins and depressed in the center. Volutions coiled upon each other at the base of the band. Angle of the spire seventy to eighty degrees. Surface characters unknown. The nature of the imbedding material is such that it has entirely destroyed the surface markings; but the form of the shell is so entirely different from any other described from rocks of the same age that it is easily recognized."

The dimensions of the type specimen are: total height about 43 mm., greatest dimensions of the last whorl 40 mm.

Remarks. This species resembles *P. tabulata* from the Coal measures more closely than any other. De Koninck has made this last species one of the typical ones of his genus *Worthenia* * and as *P. mississippiensis* is probably cogeneric with *P. tabulata* it is here placed in the genus *Worthenia.* Whitfield has made *P. textiligera* a synonym of this species, but this is certainly a mistake.

Capulus paralius (W. W.).

Pl. XX. f. 13–14.

Original description. "Shell rather below the medium size, composed of but little more than one loosely-coiled volution. Apex minute, laterally compressed; the upper half of the shell somewhat angular on the dorsum, more rapidly expanding and less angular in the outer part. Body of the shell marked by several proportionally strong, irregular plications, which give a deeply undulating or dentate character to the margin of the aperture. General form of the aperture irregular ovate. Peristome much prolonged on the anterior portion, and a little more expanded on the right side."

"Surface marked by strong concentric lamellose lines of growth, which are strongly undulated as they cross the plications."

The dimensions of the type specimen are: depth of aperture 14 mm., width of aperture 13 mm., and height of shell from the plane of the aperture 13 mm.

Remarks. The specimen represented by figure 13 is designated as the type of this species in the University of Michigan collection, the specimen represented by figure 14 being designated as a variety of the species.

* Faun. du Calc. Carb. Belg. **4**: 64.

CAPULUS VOMERIUM (Win.).

Pl. XX. f. 15.

Original description. "Shell of medium size, describing about half a direct whorl, very rapidly enlarging; peripheral (or dorsal) region elevated and surmounted by a strong, broad, rounded carina, which becomes more obtuse toward the aperture,— a shallow groove running along each side of the carina; transverse section showing an angle of about 70° toward the beak, which enlarges to about 110° near the aperture; surface of cast destitute of markings."

"Distance from front of aperture in a straight line, to most projecting portion of beak 21 mm., height of shell when resting on aperture 12 mm., summit when in this position three-fifths the distance from aperture to apex, length of aperture 17 mm., width of aperture 15 mm."

Remarks. The type of this species has not been seen, but the individual illustrated is an authentic specimen in the University of Michigan collection labeled by the author of the species. It differs from the type chiefly in being much smaller. The species can be easily recognized by its strongly carinate periphery.

IGOCERAS UNDATA (Win.).

Pl. XX. f. 16.

Metoptoma undata, Bull. U. S. G. S. 153 : 351.

Original description. "Shell of medium size, nearly erect, apex nearly central, aperture transversely slightly elliptic; body of shell most inflated in the middle, somewhat acuminate toward the apex, and contracted at the aperture. Cast nearly smooth over the body of the shell, longitudinally undulate near and at the aperture, with a few wavy concentric lines of increment."

"Height of shell 29 mm., longest diameter of aperture 27 mm."

Remarks. With the original description of the species it is said to be from "bed No. 5." but this must be a mistake, since the lithologic character of the type specimen shows conclusively that it is from the magnesian limestone bed. The species has not heretofore been referred to the genus *Igocerus*, but if that group of Capulid shells is really deserving of generic rank this species is certainly a member of the genus.

Bellerophon panneus White.

Pl. XX. f. 17-18.

Original description. "Shell subglobose, gradually expanding, except at the lateral margins, where it expands abruptly; transverse section of the volution opposite the aperture an irregular ellipse; umbilici narrow and deep, which, when not filled with the imbedding material, display the rounded sides of the volutions, which are three or four in number. The back of the shell is somewhat flattened, and has a central longitudinal elevation, which becomes a distinct carina at the front; surface marked by strong, irregular, undulating lines of growth, becoming very rough towards the front margin."

The dimensions of the type specimen are: greatest diameter of shell 37 mm., and width of aperture 35 mm.

Remarks. The accompanying illustrations of this species represent two views of the best preserved of the type specimens in the University of Michigan collection. The illustration published by Keyes * as a representative of this species is something entirely different and probably represents an undescribed species. His illustration † designated as *B. bilabiatus* is more nearly like *B. panneus*, being entirely distinct from the true *B. bilabiatus* from the Chonopectus sandstone.

CORRELATION.

The number of species in the faunas of beds No. 3. and No. 4 is so limited that the correlation of these beds will be dependent in large part upon the correlation of the subjacent and superjacent strata with their more prolific faunas. The presence of *Chonopectus fischeri* throughout these two beds, however, and the absence of any forms which especially ally the faunas to those immediately above them in the Burlington section, would seem to indicate that these two beds should be associated with the underlying Chonopectus sandstone rather than with the overlying strata. These two beds, and these alone in the Burlington section, contain specimens of the typical form of *Pugnax striaticostata*, the specimens from

* Mo. Geol. Surv. 5. *pl. 50. f. 6.*

† Loc. cit. *pl. 50. f. 3.*

the Chonopectus sandstone being so different in their characters as to probably constitute a distinct, though allied species. The typical form of this species was described from the Kinderhook strata at Kinderhook, Pike County, Illinois, but no statement is made as to what portion of the Kinderhook series the specimens were derived from. A comparison of specimens from Pike County, Illinois, with those from Burlington, shows them to be identical in character and in mode of preservation. It is possible that this species is characteristic of a definite horizon in Pike County, as it is at Burlington, in which case it may be of value in the correlation of the Pike County section when it is properly studied.

The fauna of bed No. 5, the upper yellow sandstone, may be directly compared with the fauna of the Northview sandstone in southwestern Missouri which has been described in Kinderhook Faunal Studies I. The entire Kinderhook series as represented in Greene and the neighboring counties in Missouri,* consisting of the three principal formations, Sac limestone, Northview sandstone and shale, and Pierson limestone, must be correlated with the typical Chouteau limestone of central Missouri, the Sac limestone containing a fauna which is typical of the lower Chouteau limestone as described by Swallow.† In the following table the two faunas, that of bed No. 5 at Burlington and the Northview sandstone, are arranged side by side so that a direct comparison between them may be made. Those species in the Burlington fauna which are not known from any other fauna, are marked with an asterisk.

UPPER YELLOW SANDSTONE AT BURLINGTON.	NORTHVIEW SANDSTONE.
	Zaphrentis sp. undet.
	Scalarituba missouriensis
Leptaena rhomboidalis	
Orthothetes inaequalis * * *	*Orthothetes chemungensis* ?
	Schizophoria swallovi
	Rhipidomella burlingtonensis
	Chonetes illinoisensis ?
Productus arcuatus	*Chonetes* sp. undet.
**Productus parvulus*	*Productus* sp. undet.
**Productus morbillianus*	

* Jour. Geol. **9**: 130–148.

† Geol. Surv. Mo. I. & II. Rep. (1855), p. 102.

UPPER YELLOW SANDSTONE AT BURLINGTON.	NORTHVIEW SANDSTONE.
	Productella concentrica
Spirifer marionensis * * * *	*Spirifer marionensis*
Spirifer peculiaris ? * * * *	*Spirifer peculiaris*
Spirifer centronatus	*Spirifer striatiformis ?*
	Spirifer sp. undet.
	Spiriferina sp. undet.
Cyrtina acutirostris ?	
	Syringothyris carteri
Reticularia cooperensis	
	Ambocoelia parva
	Athyris lamellosa
	Cleiothyris sp. undet.
**Dielasma allei* * * * * *	*Dielasma* sp. undet.
**Camarophorella lenticularis*	
	Crenipecten winchelli
	Crenipecten laevis
**Pterinopecten nodocostus*	
Pernopecten cooperensis * * *	*Pernopecten cooperensis*
**Lithophaga minuta*	
	Modiomorpha northviewensis
	Ptychodesma ? sp. undet.
**Macrodon parvus* * * * *	*Macrodon* sp. undet.
	Edmondia missouriensis
**Edmondia nuptialis*	
	Edmondia sp. undet.
**Edmondia strigillata*	
	Sanguinolites websterensis
**Sphenotus cylindricus*	
**Spathella phacelia*	
**Nucula iowensis*	
**Palaeoneilo microdonta* * * *	*Palaeoneilo constricta*
**Palaeoneilo barrisi* * * * * *	*Palaeoneilo truncata*
**Leda saccata*	
**Dexiobia ovata*	*Cardiopsis radiata*
**Dexiobia halli*	*Cardiopsis erectus*
**Schizodus trigonalis* * * * *	*Schizodus aequalis*
	Elymella missouriensis
	Promacrus websterensis
Promacrus cuneatus * * * *	*Promacrus cuneatus*
	Tropidodiscus cyrtolites
	Euphemus sp undet.
	Bucania sp. undet.
**Bellerophon* sp. undet.	*Bellerophon* sp. undet.
**Bucanopsis perelegens*	
	Mourlonia northviewensis
	Pleurotomaria sp. undet.
	Platyschisma missouriensis
**Straparollus* sp. undet. * *	*Straparollus* sp. undet.
Straparollus angularis	
Phanerotinus paradoxus * * *	*Phanerotinus paradoxus*
	Capulus sp. undet.
	Porcellia rectinoda ?
	Loxonema sp. undet

UPPER YELLOW SANDSTONE AT BURLINGTON.	NORTHVIEW SANDSTONE.
Dentalium grandaevum	*Orthoceras indianense*
	Triboloceras digonum
	Proetus sp. undet.
	Spirophyton sp.

A comparison of these two lists shows a large number of species in each which do not occur in the other, but at the same time certain strong bonds of relationship are exhibited. This relationship is best shown by the pelecypod genera *Pernopecten*, *Palaeoneilo* and *Promacrus*. The genus *Pernopecten* is one of the commonest forms in the Northview fauna, it is also abundant in the upper yellow sandstone at Burlington, but has an even greater representation in the superjacent oolitic limestone. In all these beds the genus is represented by a common species, *P. cooperensis*, which is also exceedingly common in some of the beds of the Chouteau limestone of central Missouri. *Palaeoneilo* is represented by two species in each of the above faunal lists, which in both cases may be considered as representative species, those in the two faunas being closely allied. The genus is largely represented in the higher Devonian faunas but is entirely absent from the Chonopectus fauna where so many Devonian genera of pelecypods are present. *Promacrus* is one of the most conspicuous genera in the Northview fauna, but only a single specimen has been observed from Burlington, which is, however, a member of one of the two Northview species. This genus is also not uncommon in some beds of the Chouteau limestone of central Missouri.

The species in the upper yellow sandstone fauna at Burlington which are known to occur in other faunas are only thirteen in number, but of this number two only, *Straparollus, angularis* and *Dentalium grandaevum* occur in the Chonopectus sandstone of the same section. *Cyrtina acutirostris* which is but doubtfully identified in the Burlington section, is certainly known elsewhere only in the Louisiana fauna. *Orthothetes inaequalis* and *Spirifer centronatus* are known from the Waverly sandstone of Ohio. The remainder of the thirteen species, *Leptaena rhomboidalis*, *Productus arcuatus*, *Spirifer marionensis*, *Spirifer peculiaris*, *Reticularia cooperensis*, *Pernopecten cooperensis*, *Promacrus cuneatus* and *Phanerotinus paradoxus*, are more or less common in the faunas of the typical Chouteau limestone of central Missouri, or in those of the same age in southwestern Missouri.

The correlation of the upper yellow sandstone at Burlington with some portion of the typical Chouteau limestone of central Missouri is assured by the paleontological evidence. Bed No. 6, the oolite limestone, also carries a Chouteau limestone fauna. The fauna is closely allied to that of the subjacent bed No. 5, but lacks the pelecypod element which constitutes so large a portion of that fauna. The only common pelecypod in the fauna is *Pernopecten cooperensis*, which is also present in bed No. 5, and which is a common form in some of the beds of Chouteau age in central and southwestern Missouri. *Chonetes logani*, a common species in the fauna, is also present in the Sac limestone of southwestern Missouri, and is possibly identical with *Chonetes ornatus* of the typical Chouteau limestone. *Productus arcuatus* and *Productella concentrica* are both well represented in the faunas of Chouteau age in Missouri. *Spirifer marionensis*, one of the commonest species of the fauna, is abundant in the typical Chouteau faunas, and is also one of the most characteristic species of the Louisiana limestone fauna.

In bed No. 7, some species, such as *Productus punctatus* and *Camarophoria caput-testudinis*, are introduced, which point forward to the following Osage faunas. Several of the other species in the fauna pass up from the beds below, and others are restricted to this bed in the Burlington section. *Rhynchonella persinuata* is closely allied to, and is possibly not distinct from *Rhynchonella cooperensis* of the typical Chouteau fauna of Cooper County, Missouri. This same introduction of Osage forms is noticeable in the upper beds of Chouteau age elsewhere, especially in the Pierson limestone of southwestern Missouri.

The paleontologic evidence points definitely to the approximate correlation of beds 5, 6, and 7 of the Burlington section, with the Chouteau limestone of central Missouri, and with the three formations known as the Sac limestone, the

Northview sandstone and shales, and the Pierson limestone, of southwestern Missouri.

In the Kinderhook section, at Louisiana, Missouri, three formations, the Louisiana limestone, the Hannibal shale and the Chouteau limestone, have been recognized by the Missouri Geological Survey.* In the lists of species from these formations at this locality, published by Keyes † and Rowley, almost the entire Kinderhook fauna is restricted to the Louisiana limestone. Only thirteen species are recorded from the Hannibal shale, and of these four are not identified specifically. With two unimportant exceptions every one of these nine species definitely recognized is present elsewhere in faunas of Chouteau age. The species recognized are the following: *Athyris hannibalensis* (= *A. lamellosa*), *Chonetes ornatus*, *Rhipidomella missouriensis* (this species is probably identical with *R. burlingtonensis* as identified from Kinderhook horizons), *Spirifer marionensis*, *Syringothyris carteri*, *Grammysia hannibalensis* (a typical specimen of this species from the Northview sandstone near Wishart, Missouri, is preserved in the collection of Walker Museum), and *Pernopecten cooperensis*. This assemblage of species may be safely considered as representing the fauna of the typical Chouteau horizon, in part, at least the fauna of the upper portion of the Kinderhook section at Burlington and the Kinderhook fauna of southwest Missouri.

The so-called Chouteau limestone of the Louisiana section, a bed with a thickness of but nine feet, contains a more prolific fauna than the Hannibal shale, twenty-eight species in all being recorded. Eighteen of these are crinoids or other echinoderms, which are for the most part Burlington limestone species, every one of them except *Rhodocrinus whitei* being originally described from the lower Burlington limestone or from the bed in question at Louisiana. *R. whitei* was described by Hall from the Chemung sandstone at Burlington and probably came from bed No. 7 at that locality. Of the other species recorded, *Zaphrentis calceola*, *Athyris*

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* Mo. Geol. Surv. **4**: 48–57.

† Proc. Io. Acad. Sci. **4**: 29.

lamellosa, *Orthis swallovi*, *Straparollus latus*, and *Igoceras quincyense* are all lower Burlington limestone species. *Cleistopora typa* which is identified with a query, is the same as *Leptopora typa* of bed No. 7 at Burlington. As has been pointed out by Keyes * this fauna is allied to that of the Burlington limestone. It is not, however, the Chouteau fauna, and the bed containing it cannot be correlated with that formation.

In recent papers Keyes † has suggested the correlation of the Chonopectus sandstone at Burlington with the Hannibal shale of the Louisiana section. The paleontological evidence, however, afforded by the same author, demonstrates the Chouteau age of the Hannibal shales, and suggests their correlation with the beds representing the Chouteau in the Burlington section which lie altogether above the Chonopectus sandstone. If such a correlation prove to be the correct one, then bed No. 4 may be considered as a northern extension of the Louisiana limestone as has been suggested in a previous paper by the writer, ‡ and the Chonopectus fauna may be considered as being pre Louisiana in age. The fauna of bed No. 4, however, contains little or nothing to suggest its correlation with the Louisiana limestone.

In a recent paper on the Carboniferous faunas of the Yellowstone National Park, Dr. Geo. H. Girty § has drawn some interesting comparisons between the fauna of the Madison limestone of that region, and the Kinderhook faunas of the Mississippi valley. He says,¶ "Considering the fauna of the Madison limestone as a whole, it can be pointed out that, of the 79 species known from this formation, 29 were described from or have been identified in Kinderhook beds of Ohio, Michigan, and the Mississippi Valley — that is, about 37 per cent of the Madison limestone fauna consists of Kinderhook species." A list of species follows and then he continues, "After making the necessary deductions from this list, some of whose identi-

* Trans. Ia. Acad. Sci. **4**: 26.—Trans. Acad. Sci. St. Louis. **7**: 357.—Am. Geol. **20**: 167.

† Jour. Geol. **8**: 315. — Am. Geol. **26**: 315.

‡ Iowa Geol. Surv. **10**: 79.

§ Monog. U. S. G. S. 32: 479–578.

¶ Loc. cit. p. 490.

fications are rather in the nature of approximations, it still must be apparent that the fauna of the Madison limestone has many peculiarities of the earlier Mississippian, and in particular shows a marked affinity throughout with the Kinderhook fauna." It is recognized by Dr. Girty, however, that it is not a pure Kinderhook fauna with which he is dealing, for he says,* "I do not believe that the facts warrant an exact correlation of the Madison limestone with the Kinderhook horizon of the Mississippi Basin, although the Kinderhook affinities of its fauna are obvious. The evidence of such genera as Endothyra, Eumetria, Archimedes, and other forms already mentioned, can not be set aside, and the probabilities involved in placing the Madison limestone, 1,700 feet thick, to offset the 300 feet of shales, sandstones, and limestones of the Kinderhook in the Mississippi Valley, are significant.

"A more probable interpretation of the facts observed seems to be that the Madison limestone represents a large portion, possibly even the whole, of the Lower Carboniferous period, being a Kinderhook fauna which through uniformity of conditions of environment had maintained its essential characters long after its contemporary fauna to the east had been superseded."

In making his comparisons between the fauna of the Madison limestone and the Kinderhook fauna, Dr. Girty makes no particular mention of any special division of the Kinderhook faunas, but rather treats them as a unit. A careful examination of his lists of species shows, however, that this relationship is especially with the Chouteau fauna of the Mississippi Valley. The following species of this fauna at Burlington, are present or are represented by closely allied species in the Madison limestone.

Yellowstone.	Burlington.
Leptaena rhomboidalis	*Leptaena rhomboidalis*
Orthothetes inflatus	*Orthothetes inflatus*
Orthothetes inaequalis	*Orthothetes inaequalis*
Chonetes ornatus	*Chonetes logani*
Productella cooperensis	*Productella concentrica*

* Loc cit. p. 493.

Yellowstone.	Burlington.
Productus parviformis	*Productus parvus*
Cleiothyris crassicardinalis	*Cleiothyris hirsuta*
Spirifer centronatus	*Spirifer centronatus*
Spirifer marionensis	*Spirifer marionensis*
Reticularia cooperensis	*Reticularia cooperensis*
Straparollus utahensis	*Straparollus obtusus*

There is little or nothing in common between the Chono pectus fauna at Burlington and the fauna described by Girty.

That the Madison limestone represents a time period much longer than the Chouteau zone of the Kinderhook, seems to be well assured, in fact it is probably the stratigraphic equivalent of all the formations in the Mississippi Valley from the Kinderhook at least up to the St. Louis limestone. In this connection it is of interest to note that in the Chouteau fauna and more especially in the fauna of the oolite bed at Burlington, there is also an element suggestive of faunas younger than the Osage. Specimens of *Cleiothyris hirsuta* not distinguishable from specimens of the same species in the Spergen Hill fauna of St. Louis age are present in the oolite fauna at Burlington. *Concardium pulchellus* has a Spergen Hill representative in *C. meekanum*, *Athyris crassicardinalis* is similar to and is perhaps identical with *Centronella crassicardinalis*, and the particular variety of *Rhipidomella burlingtonensis* present in the oolite bed at Burlington is represented by *R. dubia* in the Spergen Hill fauna.

The suggestion offered as an interpretation of all these various faunal relationships is that after the wide geographic distribution of the later Kinderhook faunas, from Ohio to beyond the Rocky Mountains, there was a withdrawal of the fauna for some reason, within the more western portion of the area it had occupied, where it continued to flourish during the period of development of the Osage faunas in the Mississippi Valley. At a much later period, the beginning of Genevieve time, this western fauna again migrated eastward and entered into the fauna of the St. Louis limestone and its stratigraphic equivalents. The recurrence, in rocks of the age of the St. Louis limestone at Batesville, Arkansas, of a fauna of much older type, even Devonian, has been recorded by Williams,* but this Batesville fauna seems to have migrated eastward from the southwestern region. The eastward migration from the northwest of the fauna containing persistent Kinderhook types, probably occurred at approximately the same time as a similar migration from the southwest the evidence of which is recorded in the rocks of Arkansas.

EXPLANATION OF ILLUSTRATIONS.

PLATES XII–XX.

(UNLESS OTHERWISE STATED, ALL FIGURES ARE OF NATURAL SIZE.)

Plate XII. — 1. *Chonopectus fischeri* (N. & P.). U. of C. Coll. No. 6655. — 2. *Chonetes gregarius* n. sp. U. of C. Coll. No. 6654. — 3. *Rhipidomella burlingtonensis* (H.) U. of C. Coll. No. 6656. — 4–7. *Holopea conica* Win. 4. Type of *H. conica*. 6. Type of *H. mira*. 7. Type of *H. subconica*. U. of M. Coll. Nos. 1459, 1460. — 8. *Microdon leptogaster* (Win.) Type specimen. U. of M. Coll. No. 1431. — 9. *Aviculopecten iowensis* Miller. Type specimen. U. of M. Coll. No. 1395.

Plate XIII.— 1–3, *Syringothyris halli* Win. Three views of the most perfect of the type specimens. U. of M. Coll. No. 1369. — 4–6. *Rhynchopora pustulosa* (White). Three views of one of the type specimens. U. of M. Coll. No. 1377. — 7–13. *Camarotoechia ? heteropsis* (Win.). 9–10. Two views of one of the type specimens, and 11–13, three views of another of the types of U. M. Coll. No. 1997. 7–8. Two views of the type of *R. unica* Win. U. of M. Coll. No. 1999.— 14–16. *Pugnax striaticostata* (M. & W.). Three views of a very perfect specimen. The radiating striae are not shown in the drawing. U. of C. Coll. No. 6658.— 17. *Chonopectus fischeri* (N. & P.). U. of C. Coll. No. 6657.

Plate XIV.— 1–2. *Spirifer marionensis* Shum. Two views of a pedicle valve. U. of M. Coll.—3–4. *Spirifer centronatus* Win. Views of a pedicle and a brachial valve. U. of C. Coll. No. 6660.— 5. *Cyrtina acutirostris* (Shum.) ? View of a brachial valve. U. of C. Coll. No. 6663.— 6–9. *Spirifer peculiaris* Shum. ? 6–7. Views of a brachial and a pedicle valve. 8. View of a wax impression from a natural mould showing an elongate hinge-line and a sharply defined cardinal area.—9. Lateral view of an internal cast. U. of M. Coll. Nos. 1362, 1363, 1413. — 10. *Dielasma allei* (Win.). The type specimen. U. of M. Coll. No. 2004.—11–13. *Camarophorella lenticularis* (W. & W.). 11. A pedicle valve, 12–13, brachial and lateral views of another specimen. Type specimens. U. of M. Coll. No. 1356.— 14–15. *Reticularia cooperensis* (Swall.). A pedicle and a brachial valve. U. of M. Coll. No. 1367.— 16–18. *Orthothetes inaequalis* (Hall). Views of three specimens, one pedicle and two brachial valves. U. of C. Coll. No. 6662.—19–20. *Leptaena rhomboidalis* Wilck. U. of C. Coll. No. 6659.— 21–22. *Productus parvulus*

* Am. Jour. Sci. **49**: 94–101.

Win. Two views of one of the type specimens. U. of M. Coll. No. 1338.— 23. *Productus arcuatus* Hall. U. of M. Coll. No. 6661.— 24–25. *Productus morbillianus* Win. Two views of one of the type specimens. U. of M. Coll. No. 2003.

Plate XV. — 1–2. *Dexiobia ovata* (Hall). Two views of Winchell's type of the genus. U. of M. Coll. No. 1425.— 3–4. *Dexiobia halli* Win. Two views of the type specimen. U. of M. Coll. No. 1403.— 5–6. *Pernopecten cooperensis* (Shum.). 5. The type specimen of *Aviculopecten limaformis* W. & W. 6. The type of the genus *Pernopecten*. U. of M. Coll. No. 1388. — 7. *Pterinopecten nodocostatus* (W. & W.). The type specimen. U. of M. Coll. No. 1390 (in part). — 8–9. *Nucula iowensis* W. & W. Two of the type specimens. U. of M. Coll. No. 1423. — 10. *Spathella phaselia* (Win.). The type specimen. U. of M. Coll. No. 1404. — 11. *Sphenotus cylindricus* (Win.). The type specimen. U. of M. Coll. No. 1413. — 12. *Edmondia strigillata* Win. The type specimen. U. of M. Coll. No. 1409. — 13. *Edmondia nuptialis* Win. The type specimen. U. of M. Coll. No. 1407. — 14. *Macrodon parvus* W. & W. The type specimen. U. of M. Coll. No. 1421. — 15–16. *Palaeoneilo microdonta* (Win.). Two of the type specimens. U. of M. Coll. No. 1424. — 17–18. *Palaeoneilo barrisi* (W. & W.). Two of the type specimens. U. of M. Coll. No. 1425. — 19. *Lithophaga minuta* n. sp. The type specimen. U. of M. Coll. No. 1401. — 20. *Leda saccata* (Win.). View of an average specimen. U. of C. Coll. No. 6667. — 21–22. *Schizodus trigonalis* (Win.). Two specimens, the larger of which is the type. U. of M. Coll. No. 1419 (in part). U. of C. Coll. No. 6666. — 23–24. *Bucanopsis perelegans* (W. & W.). The largest of the type specimens. U. of M. Coll. No. 1437. — 25. *Straparollus* sp. undet. U. of C. Coll. No. 6665. — 26–27. *Straparollus angularis* Weller. Two views of one specimen. U. of M. Coll. No. 1454. — 28. *Bellerophon* sp. undet. U. of C. Coll. No. 6664. — 29. *Dentalium grandaevum* Win. One of the type specimens. U. of M. Coll. No. 1447.

Plate XVI. — 1. *Orthothetes* sp. undet. U. of C. Coll. No. 6671. — 2–3. *Orthothetes inflatus* (W. & W.). Two of the type specimens, a pedicle and a brachial valve. U. of M. Coll. No. 1353. — 4–5. *Schizophoria subelliptica* (W. & W.). Two views of one of the type specimens. U. of M. Coll. No. 1349. — 6. *Rhipidomella burlingtonensis* (Hall)? A pedicle valve. U. of C. Coll. No. 6670. — 7–8. *Leptaena rhomboidalis* Wilck. Two views of one specimen. U. of M. Coll. No. 1347. — 9. *Chonetes burlingtonensis* n. sp. The type specimen. U. of C. Coll. No. 6669. — 10–11. *Chonetes logani* N. & P. View of a rather large specimen and an enlargement of the minute surface characters. U. of C. Coll. No. 6668. — 12–14. *Productella concentrica* (Hall). One view of a brachial and two views of a pedicle valve. U. of C. Coll. No. 6672. —15. *Productus arcuatus* Hall. Lateral view of an average specimen. U. of C. Coll. No. 6673. — 16–17. *Spirifer marionensis* Shum. A pedicle and a brachial valve. U. of C. Coll. No. 6674. — 18–24. *Athyris crassicardinalis* White. Several views of type specimens. U. of M. Coll. No. 1358 (in part). — 25–27. *Cleiothyris hirsuta* Hall. Three views of one specimen. U. of M. Coll. No. 1358 (in part).

Plate XVII. — 1. *Pernopecten cooperensis* (Shum.). A specimen of average dimensions. U. of C. Coll. No. 6675. — 2–3. *Concardium pulchellum* W. & W. Two views of the type specimen. U. of M. Coll. No. 1427. — 4–5. *Strophostylus bivolve* (W. & W.). Two views of one of the type specimens.

U. of M. Coll. No. 1444 (in part). — 6–8. *Straparollus obtusus* (Hall). Three views of a nearly perfect specimen. U. of C. Coll. No. 6676. — 9. *Loxonema* sp. undet. U. of M. Coll. No. 1450 (in part). — 10–11. *Pleurotomaria ? quinquesulcata* (Win.). Two views of the specimen supposed to be the type. U. of M. Coll. No. 2005. — 12. *Pleurotomaria ?* sp. undet. U. of C. Coll. No. 6677. — 13–14. *Orthoceras indianense* (Hall). Outline views drawn from an imperfect specimen. U. of C. Coll. No. 6678.

Plate XVIII. — 1. *Gyroceras burlingtonensis* Owen. Tracing of the original illustration of the type specimen. About one-third natural size.

Plate XIX. — 1–4. *Camarophoria caput-testudinis* (White). 1–3. Three views of the best of the type specimens from the Burlington limestone. 4. An imperfect specimen from Bed No. 7. U. of M. Coll. No. 1376. — 5. *Camarotoechia persinuata* (Win.). The specimen believed to be the type. U. of M. Coll. No. 1998. — 6–7. *Schizophoria subelliptica* (W. & W.). Two views of the type specimens. U. of M. Coll. No. 1349. — 8. *Productus punctatus* Martin. U. of M. Coll. No. 2011. — 9. *Orthothetes inaequalis* (Hall) ? U. of M. Coll. No. 1325. — 10–12. *Orthothetes inflatus* (W. & W.). Three views of one of the type specimens. U. of M. Coll. No. 1353.

Plate XX. — *Spirifer peculiaris* Shum. ? U. of M. Coll. — 2–4. *Spiriferina solidirostris* (White). Views of two of the type specimens. U. of M. Coll. No. 1372. — 5–6. *Spiriferina subtexta* White. The type specimen from the Burlington limestone. Introduced for comparison with *S. solidirostris*. U. of M. Coll. No. 1701. — 7–11. *Nucleospira barrisi* White. Two of the type specimens. U. of M. Coll. No. 1360. — 12. *Worthenia mississippiensis* (W. & W.). The type specimen. U. of M. Coll. No. 1448. — 13–14. *Capulus paralius* W. & W.). The type specimens. U. of M. Coll. Nos. 1443. 1994. — 15. *Capulus vomerium* (Win.) View of an authentic specimen. U. of M. Coll. No. 2010. — 16. *Igoceras undata* (Win.). The type specimen. U. of M. Coll. No. 1995. — 17–18. *Bellerophon panneus* White. Two views of the best of the type specimens. U. of M. Coll. No. 1435. — 19. *Leptopora typa*. Win. The type specimen. U. of M. Coll. No. 1327.

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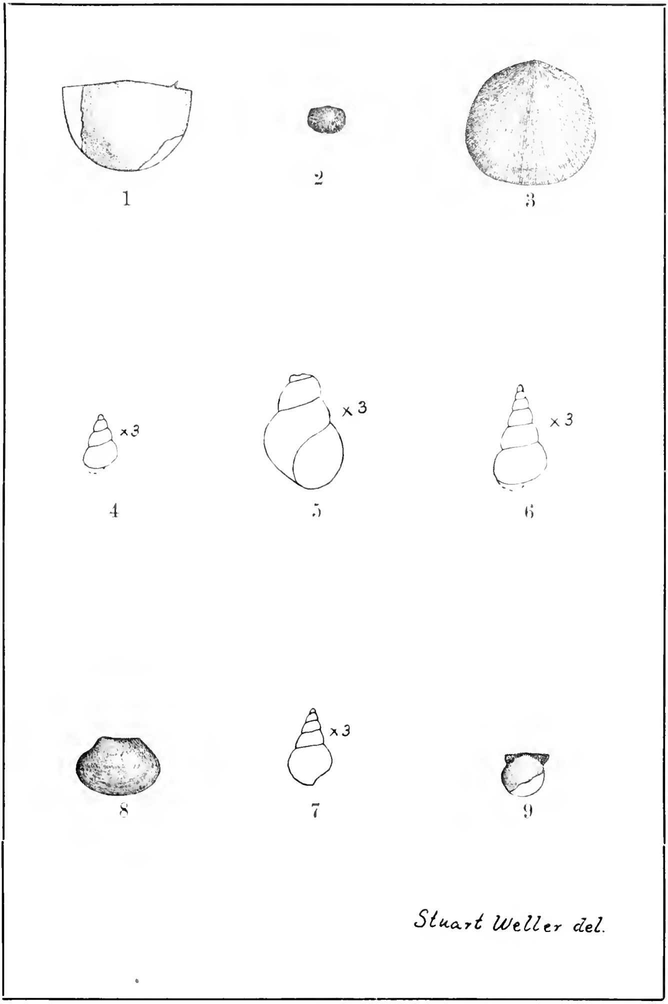

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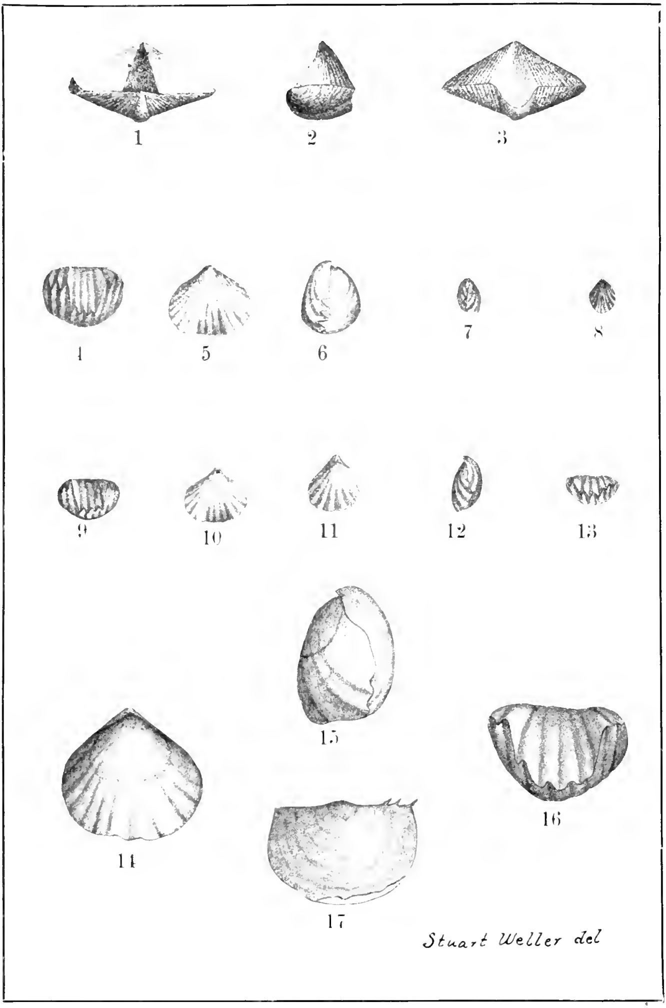

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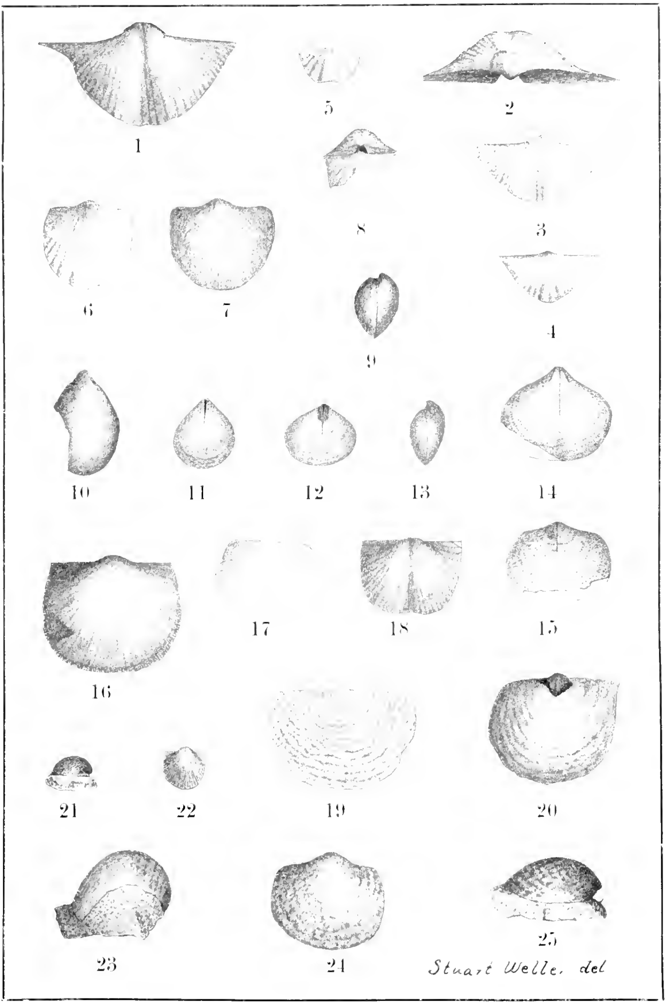

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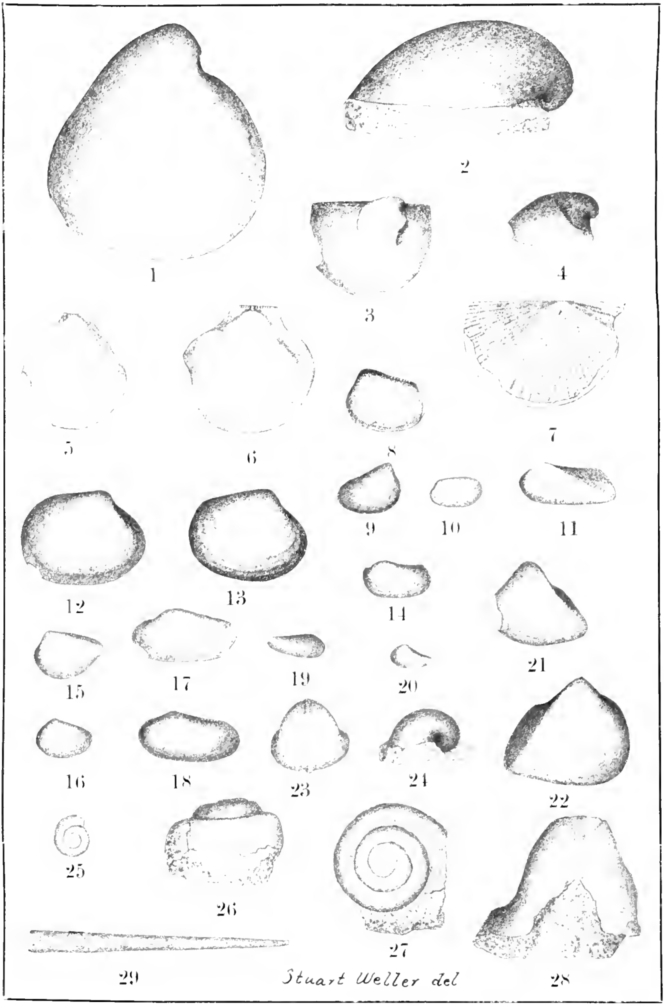

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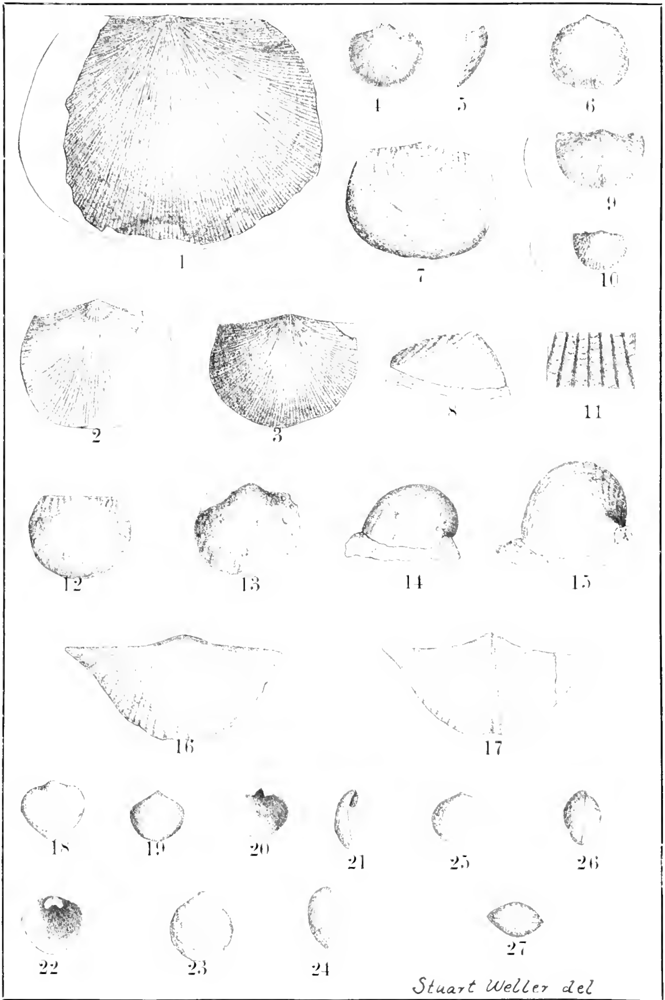

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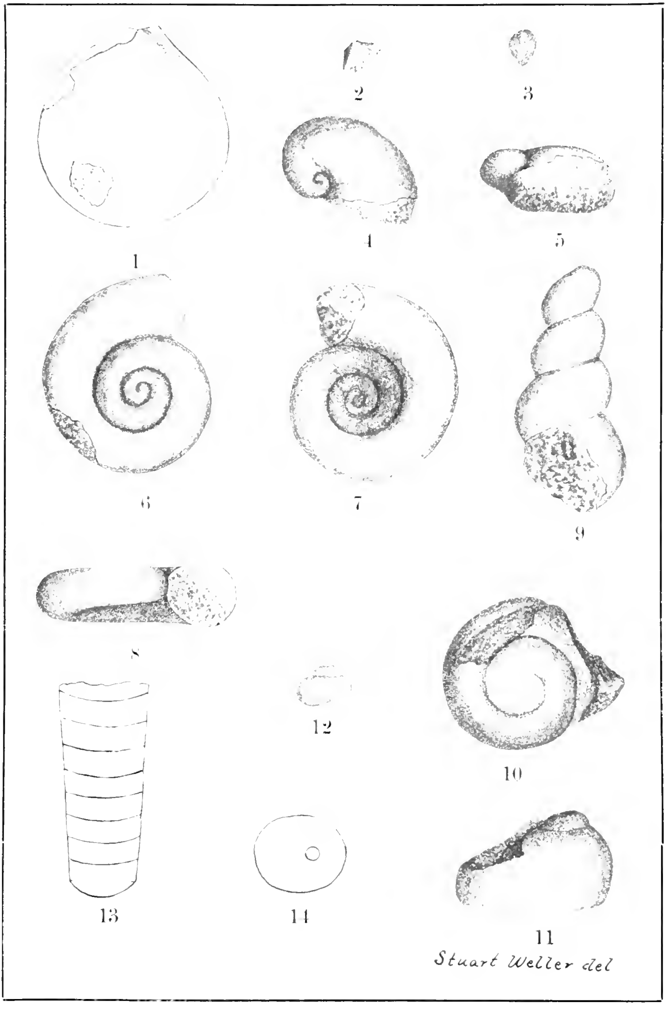

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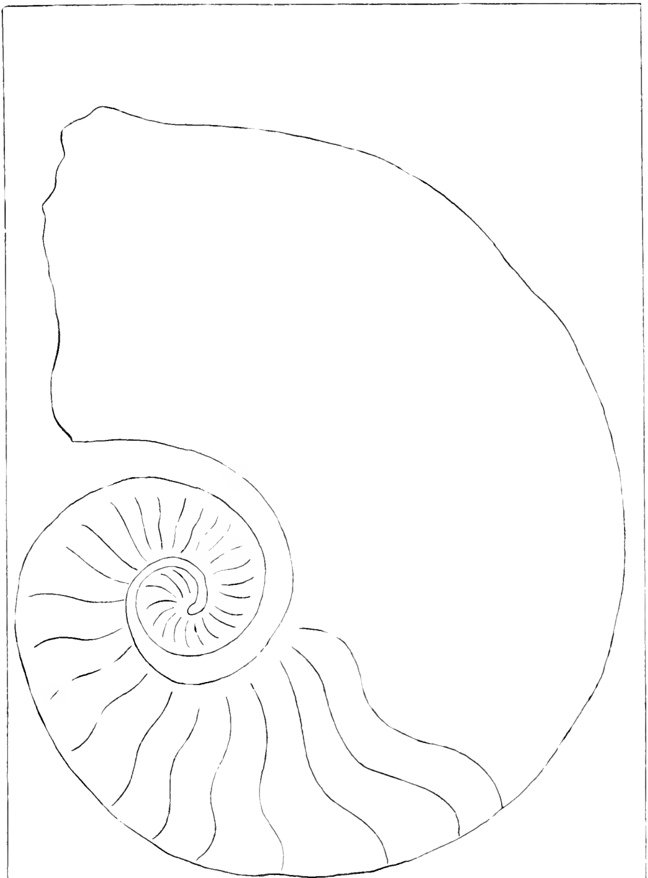

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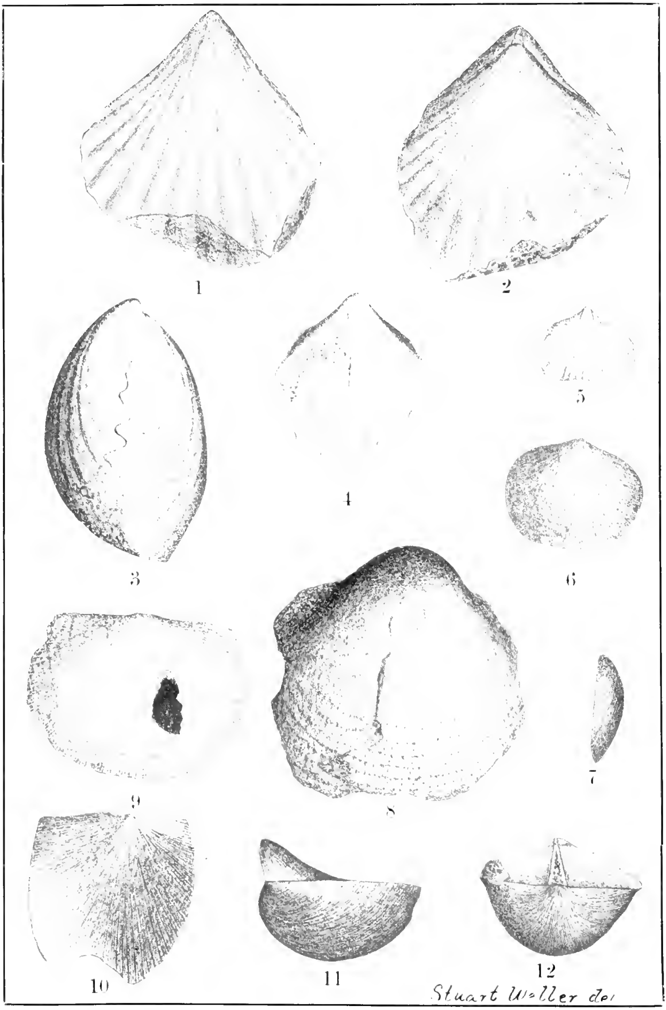

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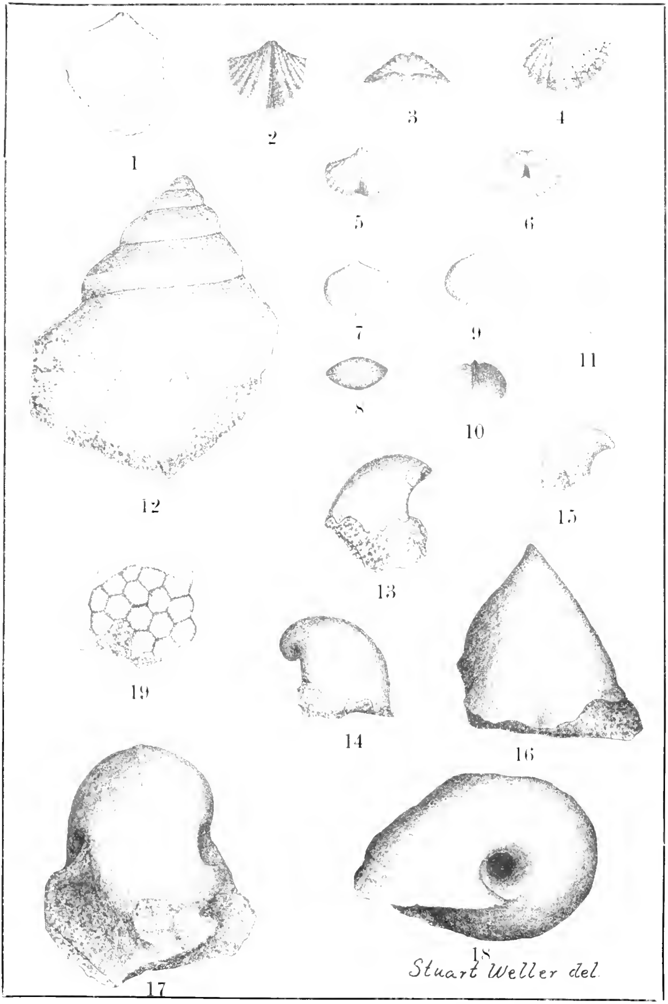

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VOL. XI. No. 10.

NORMAL AND TERATOLOGICAL THORNS OF GLEDITSCHIA TRIACANTHOS, L.

J. ARTHUR HARRIS.

Issued December 24, 1901.

NORMAL AND TERATOLOGICAL THORNS OF GLEDITSCHIA TRIACANTHOS, L.*

J. Arthur Harris.

In *Gleditschia*, a genus of wide distribution,† including ten or more species,‡ abnormalities of structure are of very frequent occurrence. Fasciation has been observed in the twig, malformations in the leaves have been noted by many writers. Synanthy is often observed. The occurrence of two carpels in otherwise single flowers is very common. Either of these cases may lead to the formation of double fruits. Deviations from the normal structure are of frequent occurrence in the seedlings. The seeds sometimes contain more than one embryo and the plants developing from them may be grown together. The occurrence of three cotyledons, splitting of the cotyledons, and the growing together of the same, either laterally or dorsally, have been observed.

The above anomalies are mentioned by Penzig,§ where refences to the literature, as well as a somewhat more extensive mention of the different cases, may be found, for *G. triacanthos*. Some of the same deformities are noted for other species of the genus and some teratological phenomena not as yet observed for *G. triacanthos* are noted for other species.

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* Presented in abstract to The Academy of Science of St. Louis, December 2, 1901.

† *Gleditschia* is found in Eastern North America and in the mountains of West Tropical Africa. It is represented by one species in Northern Persia and the Province of Talysh, south of the Caspian sea. It is widely distributed in Japan and China. In the Tertiary Period it existed in Europe. *G. amorphoides* has recently been described from South America. — See Sargent, C. S. Silva of North America. **3**: 73–80. 1892. — Taubert, P. Zur Kentniss einiger Leguminosen-Gattungen. Ber. D. B. G. **10**: 637–642. 1892.

‡ *Index Kewensis* gives eight. At least two have been since described and the Gleditschias of some regions, as China, are very imperfectly known. — See Sargent, *l. c.*

§ Penzig, O. Pflanzen-Teratologie. **1**: 404–407. 1890.

An examination of the literature shows that more of these deviations from the normal structure have been reported for *G. triacanthos* than for any other species. This may, of course, be due to its greater accessibility for study. Penzig, however, in speaking of anomalies of the leaf, says: "Die Laubblätter fast aller Gleditschien, besonders aber die von *Gl. triacanthos*, zeigen sehr häufig eine Menge von Anomalien, welche von zahlreichen Autoren studiert und beschrieben worden sind." This might indicate that *G. triacanthos* is the member of the genus especially likely to show abnormalities.

In the notes here presented I shall figure and briefly describe some variations from the usual structure noted in thorns of *Gleditschia* during the summer and autumn of 1901. The material was collected in part in Douglas County, Kansas, while I was doing work in the Botanical Laboratory of the University of Kansas, and in part in the region in and around St. Louis, and on the grounds of the Missouri Botanical Garden, where the work has been put into its present form.

Sargent * says of the thorns of *G. triacanthos:* "The spines, which are undeveloped branches, are three or four inches long, simple or three-forked, terete, very sharp and rigid, long pointed, thickened at the base, red at first and bright chestnut-brown when fully grown; they are produced on some individuals from above the axils of all the leaves, and sometimes in large numbers on the trunk and main branches, but are wanting or nearly wanting in others."

The thorns are usually nearly terete as Sargent describes them. Some are found, however, which are very much flattened. Such a case is shown in fig. 26. The branches, when present, on these flattened thorns are also frequently considerably flattened.

The branch of the thorn, when present, is subtended by a small but distinct scar, indicating the presence of a foliage leaf on the thorn before it became of such a specialized character as it is at present. This scar is also present in *G. aquatica.*

The production of thorns from adventitious buds on the

* Sargent, *l. c.*

trunk and larger branches is very common in *G. triacanthos.** The thorns produced from these adventitious buds are as a rule much larger than those produced in the regular manner on a normally developed twig. Those on the twig are rarely over 8 cm. in length and never, so far as I have observed, produce more than two branches. These branches are usually small, but in some instances may become quite large, reaching in some cases a length of 25 mm., when produced on a thorn 80 mm. in length. The thorns produced from adventitious buds are sometimes as much as 40 cm. in length, usually much branched, the branches large and frequently bearing one or two lateral branches of considerable size.

The thorns are not produced exclusively on the trunks of large trees but also on those of small shoots, sometimes on those less than an inch in diameter. These thorns are as much branched as those borne on the large trunks. They are also similar to them in form, the only difference being that of size. A thorn 32 mm. long from a sapling an inch in diameter bore six branches and a thorn 37 cm. long from a large trunk also bore six. The largest thorns are produced only on trees of considerable size. Small thorns, similar to those found on small saplings, occasionally occur on comparatively large trunks.

On the trunks the thorns are sometimes produced singly but as a rule are found grouped together, as many as three or four sometimes originating on a square centimetre, their numerous branches forming a mass of spines extending in all directions. This grouping of the spines is also noticed in young saplings. It sometimes happens that since they are so crowded the lower branches of these thorns are somewhat distorted. A rather extreme example of this is shown in fig. 37.

In *G. triacanthos* all trunks do not produce thorns alike, but many are found which are entirely free of them. I have not made sufficiently extensive observations to decide what conditions, if any may be determined, are responsible for this. Sargent † says, in discussing the size attained by *G. triacan-*

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* Thorns are also produced in the same way in *G. aquatica* and in *G. amorphoides.* — See Taubert, *l. c.*

† Sargent, *l. c.*

thos: "In less favorable situations and in poorer soil it is low, stunted, wide branched, and often covered with thorns." Whether or not it will be found that the production of thorns on the trunk is more apt to occur in individuals developing under unfavorable conditions, I cannot say.

It might seem that the production of these thorns is governed to a certain extent by inherent individual tendencies. I have not been able to account for it entirely on the basis of environment, since individuals with or without them may be found in the most widely differing localities, rich, moist bottom land as well as the poorer, dryer soil of the hills.

To find an explanation for one of the anomalies observed it will be necessary to notice the ontogeny of the normal thorn. Various explanations of its position and origin have been offered. The following * seems the most plausible. In the growing tip of the *Gleditschia* twig there is early differentiated in the axis of the leaf primordium, the meristem of the axillary shoot. As growth progresses this axillary bud is carried forward by the elongation of the main axis. The region below this axillary bud is surrounded in its earlier stages of development by the somewhat clasping base of the leaf petiole and here are formed a series of buds, beginning next the original axillary bud and passing down the stem, the lowest bud being the last formed. It will thus be seen that, although in its mature form it is removed a considerable distance from the axis of the leaf, the thorn has its origin in the original axillary bud. In subsequent vegetative periods these buds develop into foliage branches, thorns and flowers. One of the buds usually develops into a short branch, about 3–6 mm. long, bearing a rosette of once pinnate leaves which represent a very important part of the photosynthetic surface of the plant. In one of the two following years this branch usually dies but it may be continued as one of the regular foliage branches.

While the thorns on the trunk are usually much branched, all the buds produced on them usually do not develop. Fig. 35

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* See Delbrouck, Conrad. Die Pflanzen-Stacheln. Botanische Abhandlungen aus dem Gebiet der Morphologie und Physiologie. **2**: 4.—Russel, W. Recherches sur les bourgeons multiples. Ann. Sci. Nat., Botanique. vii. **15**: 95–202.—Shull, Geo. H. Accessory buds. Bot. Gaz. **21**: 166–169.

represents a case in which only the two lower buds have developed at all and fig. 36 a case in which only a bud near the end of the thorn has developed. In fig. 31 is shown a case in which the development of practically all the lateral buds seems to have been induced by an injury to the terminal growing point of the central axis. Here we have produced eleven branches from a central axis 80 mm. in length. Of these, seven are longer than, or nearly as long as, the main axis.

In July I noticed many of the perfectly formed thorns produced from adventitious buds on trees growing in the neighborhood of Lawrence, Kansas, which bore leaves below the branches. The same was noticed for trees in St. Louis, Missouri, in October. Not all the thorns thus produced were leaf-bearing but many of them were. The per cent., in some cases, might reach as high as 50. Whether or not the production of these leaf-bearing thorns is more common one year than another I cannot say.

The leaves produced on the thorns are quite variable. An extensive description is unnecessary since a glance at the figures conveys a good idea of their form. They are sometimes simple, ovate, sometimes once pinnate, of varying length and varying form of pinnae, sometimes bipinnate, or only a part of the leaflets again divided.

In speaking of leaf anomalies in this species Penzig says: "Sie treten, nach dem was ich beobachtet habe, leichter am Stock-Ausschlag auf, als an normal entwickelten Zweigen, sind daher an den zur Hecken verschnittenen oder als niedrige Sträucher gehaltenen Exemplaren häufiger, als an den Zweigen naturwüchsiger Bäume."

The production of leaves on thorns seems to be confined to those produced from adventitious buds. I have never, unless it be in one case, found any indication of such among the thorns of normal branches.

Of course, as mentioned above, some of the buds produced on these thorns do not develop into thorn branches, and it is not at all uncommon to find leaves whose axillary buds have failed to develop, as in figs. 1, 2 and 6.

It is of interest in this connection to note that in 1858

M. Baillon exhibited * to the Société Botanique de France a branched thorn of *Gleditschia* (species not recorded) bearing flowers at the extremities. Where the thorn was produced is not stated but it not improbably originated in an adventitious bud on the trunk.

On the trunks of trees in St. Louis and the surrounding regions were noticed thorns which had produced two branches, one immediately or close above the other. Several of these are figured.

While only mature material has been available for study the explanation of this seems to be as follows. There is produced in the axil of the leaf or the leaf scar on the developing thorn, the meristem of an axillary shoot, which is carried forward some distance from the axis of the leaf, and one or more supernumerary primordiums are developed below this primary axillary bud, just as in the normal twig. The production of the second, and lower, of the branches is to be accounted for by the development of a supernumerary bud. In many cases a small bud may be detected between the base of the branch and the leaf scar. In some cases the lower thorn has become abortive while its development is incomplete. Even where its development appears at first examination to be complete it is often found to be more flattened, or less terete, than the upper branch, and has something of the appearance of a blighted or withered structure. As may be seen from the figures they show no regularity as to size, being sometimes larger and sometimes smaller than the one above. In four cases, figs. 11, 14, 15 and 22, the lower branches were found producing secondary branches. In one of these cases, fig. 22, the branch of the second order was produced on the lower side of the branch, that is to say pointing towards the trunk. This is the only case I have noticed of a branch of the second order being produced on the lower side of the branch in a plane parallel to the main axis of the thorn. In a few cases these secondary branches have been observed on the upper side of the branches, as shown in fig. 28. When produced here they were sometimes found in addition to the two usual lateral thorns found farther down.

In these superposed thorns it will be noticed that one

* Bull. Soc. Bot. France. **5**: 316. 1858.

thorn is sometimes placed immediately above the other, and sometimes removed a considerable distance. Compare figs. 14, 17, 18, 19 and 22. This may be accounted for by the variation in the distance above the axis of the leaf to which the first formed bud is carried before growth in length ceases. Even where a second branch is not produced considerable variation in this distance is noticeable, the leaves being sometimes immediately, and sometimes a considerable distance, below the branch. Compare the figures on Plate XXI.

While I am not prepared to say whether the production of leaves on thorns is more common one year than another, I have been able to note, in a general way, no differences in the number of cases of superposed thorns produced in different years, the occurrence of such being seemingly equally numerous among the old, weathered thorns, which are falling off the trees, and those more recently formed.

It is certainly not without interest or significance that, on the thorn produced from an adventitious bud, the branch developing from the bud which probably corresponds to the one producing the thorns on the normal twig is almost invariably a perfectly formed thorn showing little variation in form, while the one developing from the bud which probably corresponds to the one producing the foliage branch in the normal twig shows a considerable range of variation in form.

It seems not at all improbable that it might be possible to find a complete series of gradations between the most specialized type of thorn and the foliage branch produced from adventitious buds. It is certainly difficult to determine to what class some of the material examined belongs. Figs. 28 and 29 show a stem, bearing some resemblance to the usual type of twig, developed from one of the supernumerary buds on an adventitious twig, which otherwise would have passed as a perfectly formed thorn. In Fig. 30 is seen a well-formed and branched thorn developed from one of the supernumerary buds on a twig produced from an adventitious bud on the trunk of a large tree. This occurrence was very common in the twig from which this was taken, in one case three well-formed thorns being produced.

The production of the anomalies above described seems to be confined, for the most part, to certain individuals, or at least in them occurs most frequently. The thorns produced on one trunk may be well supplied with leaves while those on another may have none. The superposed thorns may occur abundantly on some trees and not at all on others.

The same observation was made by Penzig, who says in speaking of leaves: "Sehr oft ist die Tendenz, Blattmonstrositäten hervorzubringen, an einzelne Individuen ganz besonders ausgebildet, und man kann an solchen Exemplaren Anomalien der verschiedensten Art vereint finden."

EXPLANATION OF ILLUSTRATIONS.

PLATES XXI–XXV.

Plate XXI.— 1–7. Various forms of leaf-bearing thorns produced from adventitious buds. — 1–6, × 1. — 7, × ½.

Plate XXII.— 8–9. Branches of adventitious thorns, from above, showing size of secondary branches, × 1.— 10–17. Forms of superposed thorns.— 10, × 2.— 11–17, × 1.

Plate XXIII.— 18–24. Various forms of superposed thorns from adventitious buds. — 21 shows a deflection from its course of the main axis by the strong development of lateral branches. The same thing is also to be seen in figure 27.— 18–23, × 1. — 24, about × ½.

Plate XXIV. — 25. One of six lateral branches from a thorn 29 cm. long from the trunk of a large tree, from above, showing the production of a lateral secondary branch nearer the end than is usually seen, × 1. The tip of the central axis had been broken off, a fact which may account for the very large size of two of the branches. — 26, A much flattened thorn from an adventitious twig four years old. — 27, Terminal portion of adventitious thorn, showing almost equal size of terminal portion of central axis and the last branch, also variation in the size of the branches, × 1. — 28, Node of twig from adventitious bud on trunk of large tree. The twig has all the appearance of a large but perfectly-formed thorn except that one of the supernumerary buds has developed into a twig bearing in turn two large branches in the form of thorns (see 29), × ½.— 29, A continuation of the twig from fig. 28, × ½. — 30, Node of adventitious twig showing thorn developed from supernumerary bud, × 1.

Pl. XXV.— 31. Adventitious thorn in which the development of a large number of lateral buds seems to have been brought about by an injury to the tip of the main axis, × ½.— 32, Branch from large adventitious thorn. Not as large as is sometimes found but the largest simple branch noticed, × 1. — 33, 34, Adventitious thorns which have been injured, apparently by some insect, possibly *Cicada*, laying eggs in them, × 1. — 35, Adventitious thorn producing branches only near the base, × ¾. — 36, Adventitious thorn in which only one of the buds near the end has developed. An uncommon occurrence, × ¾. — 37, Base of adventitious thorn showing deformities due to crowding, × 1.

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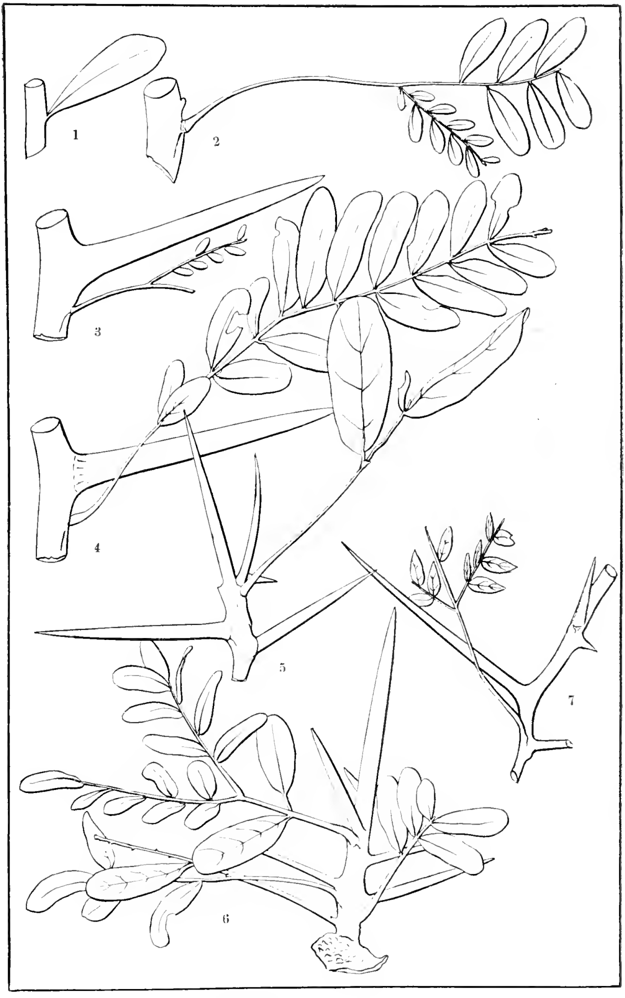

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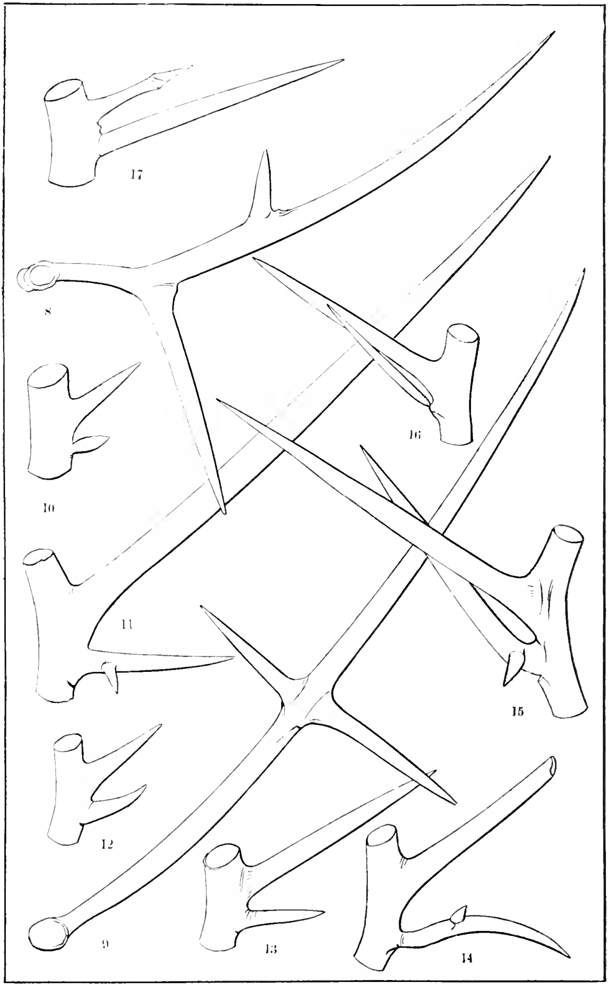

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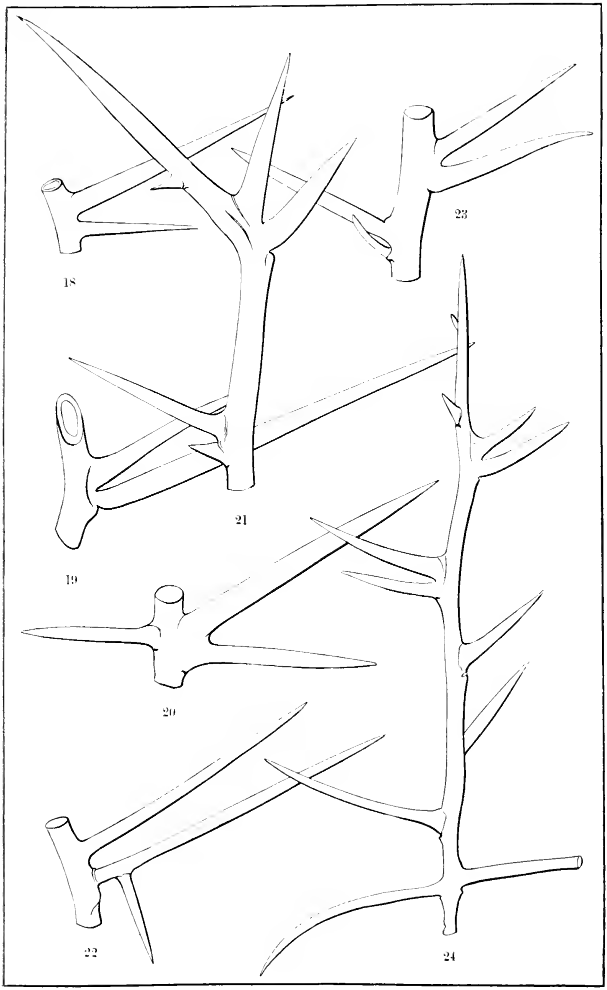

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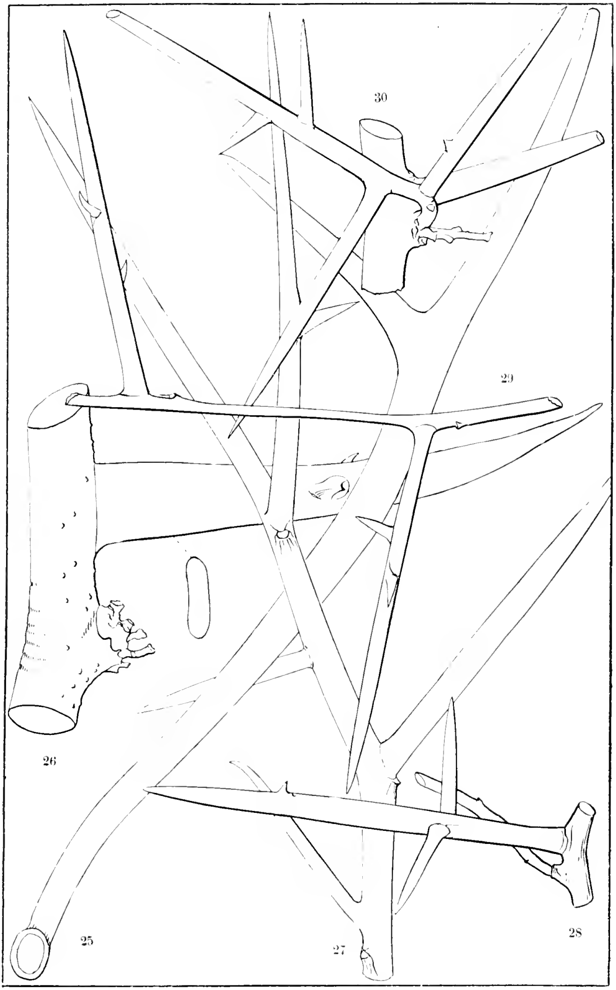

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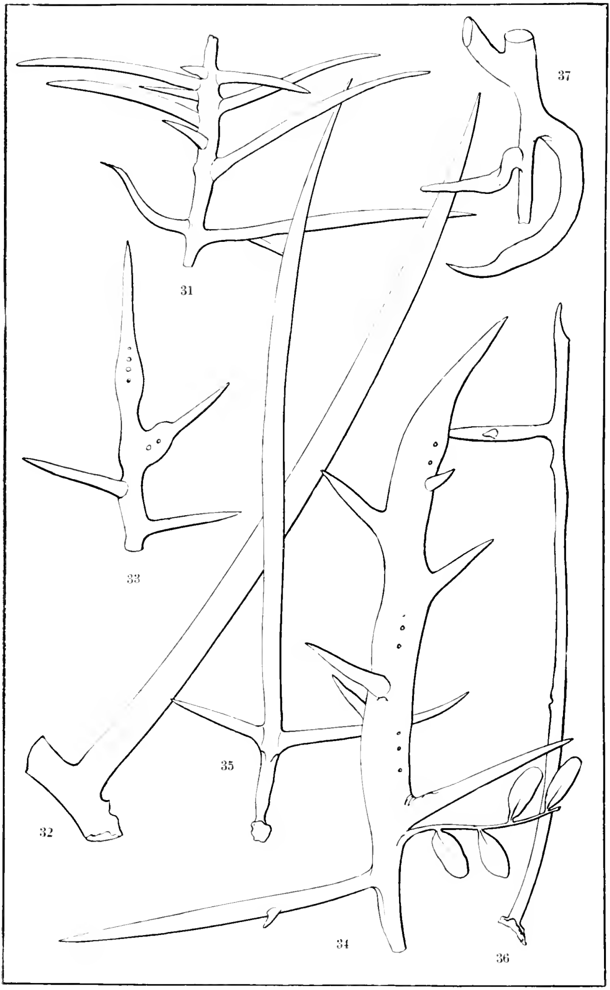

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Jones, Breckinridge...................4010 Lindell boul.

Keiser, Edward H......................Washington University.
Kennett, A. Q...........................2916 Lucas av.
Keyes, Charles R.......................944 Fifth st., Des Moines, Ia.
Kinealy, John H................ ......Washington University.
King, Goodman.........................78 Vandeventer pl.
Kirchner, Walter C. G...............4234a Easton av.
Kline, George R........................215 Pine st.
Kodis, Theodore.......................Schadowo, Government Kowno, Russia.
Krall, George Warren................Manual Training School.

Lackland, Rufus J....................1623 Locust st.
Langsdorf, Alexander S............Washington University.
Leavitt, Sherman ....1618 Indiana av., Chicago, Ill.
Lefevre, George ....State University, Columbia, Mo.
Leighton, George Bridge............803 Garrison av.
Letterman, George W................Allenton, Mo.
Lichter, John J.........................5305 Virginia av.
Loeb, Hanau Wolf......................3559 Olive st.
Ludwig, Charles V. F................1509 Chouteau av.
Lumelius, J. George..................1225 St. Ange av.
Lyon, Hartwell Nelles ....3910 Russell av.

Mack, Charles Jacob..................113 N. Broadway.
Mallinckrodt, Edward................26 Vandeventer pl.
Markham, George Dickson.........4961 Berlin av.
Marx, Christian William.............Box 73, Columbia, Mo.
Maserang, Joseph, Jr................Washington and Leffingwell avs.
Mason, Silas C..........................Berea, Ky.
Matthews, Leonard....................300 N. 4th st.
Meier, Theodore G.....................3938 Washington boul.
Merrell, Albert.........................3814 Washington boul.
Michel, Eugene H......................2721 S. King's Highway.
Miller, Charles F......................1751 Missouri av.
Monell, Joseph T......................Flat River, Mo.
Monroe, Lee Ernest...................Eureka, Mo.
Moore, Robert...........................61 Vandeventer pl.
Morton, Isaac W........................c/o Simmons Hardware Co.
Mottier, David M......................Bloomington, Ind.
Mudd, Harvey G.......................2604 Locust st.
Muegge, Aug. H........................Grand av. and Hickory st.
Mueller, Ambrose......................Webster Groves, Mo.

Nagel, Charles...........................3969 Washington boul.
Nasse, Aug..............................209 N. 2d st.
Nelson, Aven............................Laramie, Wyom.
Niedringhaus, George W........... 3745 Lindell boul.
Nipher, Francis E......................Washington University.
Norton, J. B. S.........................College Park, Md.

Oelfcken, Ernst W.....................3207 Olive st.
Oglevee, Christopher Stoner........Lincoln, Ill.
Olshausen, Ernest P..................1115 Rutger st.
Olshausen, George R.................Armour Institute, Chicago, Ill.
O'Reilly, Andrew J................. 326 City Hall.
O'Reilly, Robert J.....................3411 Pine st.
Outten, W. B...........................Mo. Pacific Hospital.
Overstolz, Herman.....................100 N. Broadway.

Palmer, Ernest Jesse.................321 S. Allen st., Webb City, Mo.
Pammel, Louis Hermann............Ames, Ia.
Pantaleoni, Guido.....................415 Locust st.
Parker, George Ward................417 Pine st.
Parsons, Charles.......................2804 Pine st.
Pauls, Gustavus.......................Eureka, Mo.
Pettus, W. H. H.......................2834 Chestnut st.

Pike, Sherman B......................5881 Cates av.
Pitzman, Julius........................1900 S. Compton av.
Poats, Thomas Grayson............Clemson College, S. C.
Post, Martin Hayward..............5371 Waterman av.
Preetorius, Emil......................c/o Westliche Post.
Prewitt, Theodore F........ ....4917 Berlin av.
Primm, Alexander T., Jr............c/o J. Kennard & Sons.
Pritchett, Henry Smith..............Institute of Technology, Boston, Mass.
Pulsifer, William H.................The Grafton, Washington, D. C.

Quaintance, A. L.....................Experiment, Ga.

Randall, John E......................1910 Olive st.
Ravold, Amand........................2806 Morgan st.
Reverchon, Julien.....................Box 229, Dallas, Tex.
Robert, Edward Scott.. ....1105 Union Trust bldg.
Roberts, Herbert F. ....Manhattan, Kas.
Robertson, Charles. ....Carlinville, Ill.
Roever, William Henry.............Cambridge. Mass.
Rogers, Herbert F.....................c/o Provident Chemical Works.
Rolfs, Peter H..........................Tropical Laboratory, Miami, Fla.
Rosenwald, Lucian...................Las Vegas, New Mex.
Runge, Edward C.....................Supt. Insane Asylum.
Russell, Colton ....Los Angeles, Calif.

Sander, Enno...........................2807 Lawton av.
Sargent, Charles Sprague...........Jamaica Plain, Mass.
Schmalz, Leopold ....2824 Shenandoah av.
Schneck, Jacob ....Mt. Carmel, Ill.
von Schrenk, Hermann...............Shaw School of Botany.
Schroers, John.........................1730 Missouri av.
Schrowang, Otto......................122 N. 3d st.
Schwab, Sidney I.....................2602 Locust st.
Schwarz, Henry......... ....1723 Chouteau av.
Schweitzer, Paul......................Columbia, Mo.
Scott, Henry C.........................64 Vandeventer pl.
See, Thomas Jefferson Jackson ..Naval Observatory, Washington, D. C.
Selby, Augustine Dawson..........Wooster, O.
Senseney, E. M........................2829 Washington av.
Sheldon, Walter L....... ....4065 Delmar av.
Shepley, John F.......................60 Vandeventer pl.

Shoemaker, Wm. Alfred............4386 Westminster pl.
Simmons, E. C........................9th and Spruce sts.
Simmons, W. D........................9th and Spruce sts.
Sluder, Greenfield.....................2647 Washington av.
Smith, Arthur George...............422 N. Dubuque st., Iowa City, Ia.
Smith, D. S. H........................3646 Washington boul.
Smith, Irwin Z.........................87 Vandeventer pl.
Smith, Jared G........................Honolulu, Hawaiian Islands.
Soldan, F. Louis.......................3634 Flad av.
Spiegelhalter, Joseph................2166 Lafayette av.
Starr, John E..........................258 Broadway, New York City.
Staudinger, B...........................3556 Lindell boul.
Stedman, John Moore...............State University, Columbia, Mo.
Stevens, Charles D....................1749 S. Grand av.
Stevens, Wyandotte James..........5377 Cabanne av.
Stocker, George J.....................2833 S. King's Highway.
Stone, Charles H.......................5562 Clemens av.
Strauss, Julius C.......................3516 Franklin av.
Stuart, James Lyall...................5346 Maple av.
Sutter, Otto..............................3035 Bell av.

Taussig, Albert E......................2318 Lafayette av.
Taussig, William.......................3447 Lafayette av.
Teichmann, William C................1141 Market st.
Terry, Robert James..................2726 Washington av.
Thacher, Arthur.........................4304 Washington boul.
Thiele, Albert...........................2746 Park av.
Thilly, Frank............................601 Hitt st., Columbia, Mo.
Thom, Charles...........................State University, Columbia, Mo.
Thomas, John R ....420 N. 4th st.
Thomson, Wm. H., Jr................3805 Lindell boul.
Thurman, John S.......................416 Lincoln Trust bldg.
Timmerman, Arthur H...............2633 Park av.
Tittmann, Harold H...................3726 Washington boul.
Trelease, William......................Mo. Botanical Garden.
Tyler, Elza Edward...................State University, Columbia, Mo.
Tyrrell, Warren Ayres...............3620a Folsom av.

Updegraff, Milton......................2505 Wisconsin av.,
Washington, D. C.

Vallé, Jules F...........................3303 Washington av.
VanOrnum, John Lane..............Washington University.

Vickroy, Wilhelm Rees..............2901 Rauschenbach av.
von Schrader, George F.............Wainwright bldg.
von Schrader, Otto U................ 3749 Westminster pl.

Warren, William Homer.............1806 Locust st.
Watts, Millard F........................4362 Morgan st.
Weller, Stuart ....University of Chicago,
Chicago, Ill.
Westgate, John Minton..............6023 Ellis av., Chicago, Ill.
Wheeler, H. A..........................3124 Locust st.
Whelpley, Henry Milton.............2342 Albion pl.
Whitaker, Edwards...................300 N. 4th st.
Whitten, John Charles...............Columbia, Mo.
Whittier, Charles Thurston .. ..92 St. James pl., Brooklyn, N. Y.
Widmann, Otto....................... Old Orchard, Mo.
Winkelmeyer, Christopher..........3540 Lawton av.
Winslow, Arthur.......................104 W. 9th st., Kansas City, Mo.
Wislizenus, Frederick A............3628 Cleveland av.
Witt, Thomas D. ....Rushville, Ill.
Wood, Obadiah M ....3016 Caroline st.
Woodward, Calvin Milton...... ... Washington University.

Zahorsky, John........................1460 S. Grand av.

THE ACADEMY OF SCIENCE OF ST. LOUIS.

ORGANIZATION.

The Academy of Science of St. Louis was organized on the 10th of March, 1856, in the hall of the Board of Public Schools. Dr. George Engelmann was the first President.

CHARTER.

On the 17th of January following, a charter incorporating the Academy was signed and approved, and this was accepted by vote of the Academy on the 9th of February, 1857.

OBJECTS.

The act of incorporation declares the object of the Academy to be the advancement of science and the establishment in St. Louis of a museum and library for the illustration and study of its various branches, and provides that the members shall acquire no individual property in the real estate, cabinets, library, or other of its effects, their interest being usufructuary merely.

The constitution, as adopted at the organization meeting and amended at various times subsequently, provides for holding meetings for the consideration and discussion of scientific subjects; taking measures to procure original papers upon such subjects; the publication of transactions; the establishment and maintenance of a cabinet of objects illustrative of the several departments of science, and a library of works relating to the same; and the establishment of relations with other scientific institutions. To encourage and promote special investigation in any branch of science, the formation of special sections under the charter is provided for.

MEMBERSHIP.

Members are classified as active members, corresponding members, honorary members and patrons. Active membership is limited to persons interested in science, though they need not of necessity be engaged in scientific work, and they alone conduct the affairs of the Academy, under its constitution. Persons not living in the city or county of St. Louis, who are disposed to further the objects of the Academy by original researches, contributions of specimens, or otherwise, are eligible as corresponding members. Persons not living in the city or county of St. Louis are eligible as honorary members by virtue of their attainments in science. Any person conveying to the Academy the sum of one thousand dollars or its equivalent becomes eligible as a patron.

Under the by-laws, resident active members pay an initiation fee of five dollars and annual dues of six dollars. Non-resident active members pay the same initiation fee, but annual dues of three dollars only. Patrons, and honorary and corresponding members, are exempt from the payment of dues. Each patron and active member not in arrears is entitled to one copy of each publication of the Academy issued after his election.

Since the organization of the Academy, 926 persons have been elected to active membership, of whom, at the present time, 287 are carried on the list. One patron, Mr. Edwin Harrison, has been elected. The list of corresponding members (Vol. X. p. xii) includes 205 names, among which are the names of 102 persons known to be deceased.

OFFICERS AND MANAGEMENT.

The officers, who are chosen from the active members, consist of a President, two Vice-Presidents, Recording and Corresponding Secretaries, Treasurer, Librarian, three Curators, and two Directors. The general business management of the Academy is vested in a Council composed of the President, the two Vice-Presidents, the Recording Secretary, the Treasurer and the two Directors.

The office of President has been filled by the following well-known citizens of St. Louis, nearly all of whom have been eminent in some line of scientific work: George Engelmann, Benjamin F. Shumard, Adolphus Wislizenus, Hiram A. Prout, John B. Johnson, James B. Eads, William T. Harris, Charles V. Riley, Francis E. Nipher, Henry S. Pritchett, John Green, Melvin L. Gray, Edmund A. Engler, and Robert Moore.

MEETINGS.

The regular meetings of the Academy are held at its rooms, 1600 Locust Street, at 8 o'clock, on the first and third Monday evenings of each month, a recess being taken between the meeting on the first Monday in June and the meeting on the third Monday in October. These meetings, to which interested persons are always welcome, are devoted in part to the reading of technical papers designed for publication in the Academy's Transactions, and in part to the presentation of more popular abstracts of recent investigation or progress. From time to time public lectures, calculated to interest a larger audience, are provided for in some suitable hall.

The following dates for regular meetings for the year 1902 have been fixed by the Council: —

Jan.	Feb.	Mar.	April.	May.	June.	Oct.	Nov.	Dec.
6	3	3	7	5	2		3	1
20	17	17	21	19		20	17	15

LIBRARY.

After its organization, the Academy met in Pope's Medical College, where a creditable beginning had been made toward the formation of a museum and library, until May, 1869, when the building and museum were destroyed by fire, the library being saved. The library now contains 14,164 books and 10,350 pamphlets, and is open during certain hours of the day for consultation by members and persons engaged in scientific work.

PUBLICATIONS AND EXCHANGES.

Eleven thick octavo volumes of Transactions have been published since the organization of the Academy, and widely distributed. Two quarto publications have also been issued, one from the Archaeological section, being a contribution to the archaeology of Missouri, and the other a report of the observations made by the Washington University Eclipse Party of 1889. The Academy now stands in exchange relations with 561 institutions or organizations of aims similar to its own.

MUSEUM.

Since the loss of its first museum, in 1869, the Academy has lacked adequate room for the arrangement of a public museum, and, although small museum accessions have been received and cared for, its main effort of necessity has been concentrated on the holding of meetings, the formation of a library, the publication of worthy scientific matter, and the maintenance of relations with other scientific bodies.

December 31, 1901.

RECORD.

From January 1, 1901, to December 31, 1901.

January 7, 1901.

President Engler in the chair, thirty-one persons present.

The nominating committee reported that 128 ballots had been counted, and the following officers for 1901 were declared duly elected: —

President	Edmund A. Engler.
First Vice-President	D. S. H. Smith.
Second Vice-President	M. H. Post.
Recording Secretary	William Trelease.
Corresponding Secretary	Hermann von Schrenk.
Treasurer	Enno Sander.
Librarian	G. Hambach.
Curators	G. Hambach, Julius Hurter, Robert J. Terry.
Directors	H. W. Eliot, Adolph Herthel.

The President delivered an address on the condition of the Academy and its work during the year 1900.*

The Treasurer submitted his annual report, showing invested funds to the amount of $6,500.00 and a balance of $450.26 carried forward to the year 1901.†

The Librarian submitted his annual report.‡

The resignation of Dr. J. K. Bauduy, Mr. Holmes Smith, Professor J. B. Johnson and Mr. F. N. Judson was reported by the Council.

Professor J. M. Stedman, of the University of Missouri, gave an interesting account of a personal examination of the life-zones of Mexico, made by him last summer, in the course of which he crossed the continent from Vera Cruz to Man-

* Transactions **10**: lxvi. † Transactions **10**: lxix. ‡ Transactions. **10**: lxix.

zanillo, making the ascent of Popocatepetl to the summit in doing so. The address was illustrated by a large series of lantern slides, presenting some of the more striking features of the physiography and vegetation of the country, and illustrating the customs of the Mexicans.

Messrs. John E. Conzelman, Otto Schrowang and W. H. Thomson, Jr., of St. Louis, were elected to active membership.

Three persons were proposed for active membership.

January 21, 1901.

President Engler in the chair, twenty-seven persons present.

The death of Mr. Charles P. Chouteau, a charter member of the Academy, and the resignation of Professor L. T. More, were reported by the Council.

Rev. M. S. Brennan read a short sketch of the progress of astronomy in the United States, in which the material equipment and discoveries made in that science in this country during the past century were passed in review.

A paper by Professor T. G. Poats, entitled Isogonic projection, was presented in abstract by Professor Nipher.

Professor F. E. Nipher showed by means of the lantern a series of negatives printed by contact from a lantern slide or positive picture, by the light of a 300 candle incandescent lamp. The unit of exposure adopted was one lamp-meter-second. The exposures varied from 0.0054 to 4800. All were developed in the dark-room with hydrochinon, those above 0.1 exposure having in the bath one drop of saturated hypo to the ounce of bath. The plate having an exposure of 0.1 seemed to be normally exposed. An exposure 210 gave a negative showing some fogging, but a print from it by ordinary methods gave a very satisfactory result. With longer exposures, the plate began to reverse, locally. With an exposure of 3600, which was an exposure of one hour at a distance of one meter from a 300 candle lamp, half of the plate still showed as a negative. The shadow on the gown of a figure in the landscape showed white as a negative, and the part of the gown in sunshine showed white as a positive. The penumbra between light and shadow was darker. All the details were sharp, but lights and shadows were somewhat incongruous. With an exposure of 4800 the details had not yet all reversed, but the greater part of the plate had become a positive.

The greatest exposure giving a negative which would yield an acceptable print was 210, which was 39,000 times the least exposure which would give a good negative. All exposures of 210 and over gave complete positives when the plates were developed 1.41 meter from a 16 candle lamp, or in stronger light. As good a picture as has been obtained had an exposure of 4800, and was developed within half a meter of a 300 candle lamp. A fair picture had even been obtained from a two-hour exposure to direct sunlight with a Cramer "Crown" plate.

It was stated that hypo in the developing bath did not affect the zero condition, or change the character as to positive and negative. When no hypo is used, the plate fogs so quickly that the picture is invisible, before it has time to fully develop. After fixing, the thin shadowy picture showing on the fogged plate has the same local positive and negative characters that are shown on the clearly defined picture of the same exposure, when developed in the hypo-hydrochinon bath.

The greatest exposures giving good results that have been measured with reasonable accuracy were about 900,000 times as great as the least exposure giving a good negative in the dark-room. This factor can certainly be trebled. A plate having any intermediate exposure can be developed either as a good positive in the light, or as a good negative in the dark-room.

It was stated that the best results with plates near the zero condition had been reached with a rather strong bath, with two drops of saturated hypo to the ounce of bath.

Messrs. W. G. Chappell and Sherman Leavitt, of St. Louis, and Mr. Ernest Howard Favor, of Columbia, Missouri, were elected to active membership.

Four persons were proposed for active membership.

February 4, 1901.

President Engler in the chair, thirty-eight persons present.

An invitation from the K. K. zoologisch-botanische Gesellschaft, of Vienna, was presented, for the Academy to participate in its fiftieth anniversary session on March 30, and on motion the Corresponding Secretary was instructed to extend the congratulations and well wishes of the Academy to the officers of that Association, together with the Academy's regret that it could not be personally represented at the meeting.

Professor F. E. Nipher showed, by means of the lantern, positive and negative photographic pictures developed from plates equally exposed, and positives reproduced from each. He outlined briefly the character of the work which he is now prosecuting on this subject, and stated that since his last communication he had succeeded in still further shortening the duration of the exposure necessary to secure good positives, so that he appeared to be rapidly realizing his hope that it will shortly be possible to convert any plate, which on the beginning of the development in the dark room shows too great exposure to yield a good negative, into a positive, by leading it beyond the zero point and completing the development in the light.

Messrs. W. N. Graves and George C. Hitchcock, of St. Louis, Dr. Lee E. Monroe, of Eureka, Missouri, and Mr. W. L. Sachtleben, of Alton, Illinois, were elected to active membership.

Two persons were proposed for active membership.

February 18, 1901.

President Engler in the chair, twenty-three persons present.

The Council reported the resignation of Dr. L. C. McElwee.

On behalf of a committee appointed at a previous meeting to present a suitable memorial of the late Charles P. Chouteau, a charter member of the Academy, Dr. Green presented the following report, which was ordered entered on the minutes and transmitted to the family of the late Mr. Chouteau: —

IN MEMORIAM.

CHARLES PIERRE CHOUTEAU.

Born, in St. Louis, December 2, 1819; died, in St. Louis, January 5, 1901.

March 10, 1856, The Academy of Science of St. Louis was organized; a constitution and by-laws were adopted, and officers elected. The name of Charles P. Chouteau appears in the minutes as a member of the Board of Council; it is the only name carried on the roll of active members at the beginning of the new century. Of the fifteen founders who took part in the meeting for organization, but one now remains affiliated as a corresponding member; two others are still living in St. Louis.

The establishment of a museum by the Academy dates from its second meeting, April 21, 1856; at this meeting "Mr Charles P. Chouteau stated that he would place the collection of fossil remains, obtained by Dr. Hayden from the *Mauvaises Terres* and other parts of Nebraska, now in his possession, in the Museum of the Academy . . . His own interest in the collection, amounting to about one-fourth of the whole, he presented as a donation." A second one-fourth interest in this very important collection, "of Mammalian and Chelonian remains from the Eocene Tertiary, together with a large suite of elegantly preserved fossils from the Cretaceous Formation of Nebraska," was acquired a year later by subscription; the other half having become the property of the Academy of Natural Sciences of Philadelphia. The museum was rapidly increased by a great number of valuable donations, and occasionally by purchases, noted in the minutes of successive meetings down to the outbreak of the Civil War, in 1861 Prominent among the donors appears, again and again, the name of Charles P. Chouteau, whose continuing interest is shown both by his very numerous gifts of important specimens and by his repeated acts of enlightened liberality in providing for a collector or other representative of the Academy to accompany him, as his guest, on the annual steamboat expeditions of the American Fur Company to the Upper Missouri Frequent notices in the Journal of Proceedings testify to the extent and the value of the additions made to the Museum from these trips. By the destruction of the collections of the Academy, by fire, in May, 1869, the visible evidence of the munificence of Mr. Chouteau and other early benefactors has been obliterated; the magnitude of the loss may be inferred, rather than estimated, from the too brief notices contained in the minutes as published in the first and second volumes of the Transactions. The fragment of a large meteorite from Nebraska, presented May 17, 1858 (*vide* Transactions, Vol. 1 pp. 711–12, Plate XXI), alone remains of the many and priceless gifts of Charles P. Chouteau to the Academy.

At the Annual Meeting, January 12, 1857, Charles P. Chouteau was elected to the office of Second Vice President; in an act of the General Assembly of the State of Missouri, approved January 17, 1857, his name appears as a Charter Member, in conjuction with †George Engelmann, †Hiram A. Prout, Nathaniel Holmes, †Benjamin F. Shumard, †Charles W. Stevens, †James B. Eads, †Moses M. Pallen, †Adolphus Wislizenus, †Charles A. Pope, and William M. McPheeters.

As a young man, Charles P. Chouteau engaged in the trading enterprises of the American Fur Company, in whose service he spent much time in the Territories of the Northwest. He was the first and only navigator who took steamboats up the Missouri river from St. Louis to Fort Benton. Inheriting property from his father, Pierre Chouteau, he added largely to it. He became a large owner in the famous Iron Mountain and engaged in the production and working of iron on an extensive scale. Himself educated as an engineer, he took a kindly interest in studious and progressive young men and found pleasure in assisting them. During his long life his interests were identified with the growth and development of St. Louis; his name will be remembered as one of her best and most honored citizens.

As a benefactor and steadfast supporter of the Academy, from its inception, Charles P. Chouteau stands for us as a type of the busy and successful man of affairs, endowed with a keen appreciation of what is highest and best in human endeavor, and ever lending a willing hand to earnest workers in science.

John Green,
Enno Sander,
Francis E. Nipher.

Professor J. L. Van Ornum addressed the Academy on The progress made in engineering during the nineteenth century.

A paper by Professor P. H. Rolfs, entitled Florida lichens, was presented by title.

Professor F. E. Nipher exhibited two photographic negatives, developed by an ordinary pyro developer. One plate had been exposed in a printing frame for 1,000 seconds at a distance of a meter from a 300 candle lamp. It was then treated for ten minutes in a chromic acid bath having ten drops of an eight per cent. solution of chromic acid to three ounces of water. This treatment was in the dark-room. The plate was then developed in the dark-room.

The exposure of the other plate had been equivalent to a tenth of a second at the same distance from the lamp, and was exposed under the same plate. This plate developed normally in a pyro developer, having six drops of bromide and six drops of potassium ferro-cyanide, both in ten per cent. solutions. The over-exposed plate showed more of detail, but the contrasts were less strong than in the plate with normal exposure. It looked like a slightly under-exposed plate.

When a plate with this exposure is treated with the chromic acid bath while in the light and is then developed in the light, a positive picture results. The chromic acid bath may be replaced by ten drops of saturated potassium bichromate solution, and four drops of common C. P. nitric acid, to three ounces (90 cc.) of water. There is reason to believe that any camera exposure which was intended to be correct may be developed as a positive in the light by such methods. It is certain that it may be handled as a negative in the dark-room.

Professor Nipher stated that if either a negative or a positive had been started and had resulted in a failure, due to improper treatment, the picture with the fog on the plate might be chemically destroyed by chromic acid, and the picture might be redeveloped in either case either as a negative in the dark-room or as a positive in the light.

It was also stated that one plate had been developed as a superb negative at a distance of a meter from a 300 candle lamp. This case was very remarkable, because, on account of an accident in the treatment, a failure or a poor positive had been expected. Several repetitions of this treatment had failed to yield this result again.

It is frequently observed that with a strong pyrocatechin developer the picture will start as a negative in the light, and will reach a fair degree of excellence, and then reverse. This is all in the nature of an oscillation such as is known in electric discharges. The phenomenon is not observed in a weaker or in a more slowly acting bath. The anomalous case before referred to could hardly be accounted for in this way, because the picture developed very slowly in a normal hydrochinon bath, and grew steadily better until it was sharply defined on the back of the film. This case is still being examined.

Mr. George A. Held and Dr. George Homan, of St. Louis, were elected to active membership.

One person was proposed for active membership.

March 4, 1901.

President Engler in the chair, fourteen persons present.

The Council reported that at their request Professor T. H. Macbride and Mr. W. L. Sachtleben, who had not qualified, had been dropped from the list of members.

An invitation for the Academy to be represented at the fifth International Congress of Zoology, to be held in Berlin, August 12–16, 1901, was presented and referred to the Council [which subsequently designated Mr. Julius Hurter as the representative of the Academy at the Congress].

The Corresponding Secretary read a communication from Dr. Amos Sawyer, entitled Ethnographic life lines left by a prehistoric race, the paper being illustrated by sketches, fragmentary human remains, and stones believed by him to be stone implements, but not necessarily such, derived from a prehistoric grave examined some ten miles southwest of Hillsboro, Illinois, on the west side of Shoal Creek. In one instance it was stated that a grave consisting of six large slabs of limestone contained six skeletons, their thighs flexed upon the abdomen, the legs upon the thighs, their arms placed by their sides and their heads at either end of the inclosing box and facing east and west. From the limited capacity of the slab-inclosed graves, the writer inferred that the remains had been placed in them after skeletonization, as there was not sufficient room for the number of bodies found unless the muscles had been removed, and it was argued from this that the remains were those of men prominent in the nation.

The Corresponding Secretary read a further communication from Dr. Sawyer, referring to a piece of wood found at a depth of 400 feet below the surface, in sinking a shaft for a coal mine. The specimen was said to have occurred in a ten-foot layer of loam filled with the debris of a forest, and the specimen submitted, like others, had been flattened by pressure.

In the discussion of these communications, Mr. Colton Russell stated that west of St. Louis, in a number of so-called Indian graves which he had examined, the encasing with rough limestone slabs, mentioned by Dr Sawyer, had been observed, and Dr. Trelease called attention to the fact that the specimen of wood exhibited, which did not seem to be petrified, belonged to post-glacial times and was perhaps comparable with certain pieces of wood, supposed to be cedar, but not yet carefully studied, which Mr. Hermann, the Sewer Commissioner of St. Louis, had found in company with bones of the early bison in the glacial detritus through which a storm sewer is being excavated at Tower Grove.

A paper by Dr. T. Kodis, On the action of the constant current upon animal tissue, was presented by the Secretary and read by title.

Professor F. E. Nipher stated that he wished to take this occasion to correct some misapprehensions concerning the development of photographic positives. He stated that the effect of development in the light was to make the normal exposure for positives shorter than when they are developed in the dark-room. When for a given illumination of the developing room the exposure has been properly made, the ordinary developer used for negatives may also be used for positives, without any restrainer. The restrainer is only needed when the plate to be developed as a positive has been under-exposed, or the plate to be developed as a negative has been over-exposed. In both cases it is an approach to the zero condition which calls for the restrainer.

Professor Nipher added that Mr. Cockayne, of the Heliotype Company, of Boston, had suggested to him the use of potassium ferro-cyanide in place of potassium bromide in developing positives, and he had found it to give great brilliancy to the pictures. A Cramer "Crown" plate exposed in a printing frame for a couple of minutes at a south window, just out of the direct rays of the sun, under a thin negative or positive, may be developed at the same place. A few drops of ten per cent. solution of the ferro-cyanide may be added, and even as much as one part in twelve of developer has yielded excellent results. The bath has in some cases been wholly made up of the ferro-cyanide solution, the other chemicals being added in dry form. The action of the ferro-cyanide is quite different from that of bromide in equal strength, although it may be largely a matter of degree.

This bath should not be quite so strongly alkaline as for negatives, in order to get the best results. The best results when positives are developed in daylight are as fine as can be obtained in the dark-room in the ordinary developing of negatives. Various developers have been tried, but none of them have yielded as good results as hydrochinon.

Mr. G. Pauls laid before the Academy a branch of a small hackberry (*Celtis*) which had become completely covered with the small nodular galls frequently borne in smaller quantities by the hackberry, and called attention to the fact that in this particular case the natural enemies of the gall-forming creatures seemed to have been absent, allowing the unusual multiplication.

Dr. Albert Habermaas, of St. Louis, was elected to active membership.

Three persons were proposed for active membership.

March 18, 1901.

President Engler in the chair, forty-three persons present.

Professor Edward H. Keiser delivered an address on Progress in the science of chemistry during the nineteenth century.*

Professor F. E. Nipher exhibited pieces of pine board a foot square, showing the tracks of ball lightning discharges upon them like those formerly described by him in No. 6, Volume X, of the Transactions of the Academy. The discharges formerly described had been formed on a photographic film. The balls were very small, and wandered over the plate, leaving a track of metallic silver in their wake. In the present instance the balls were much larger, and they burned a deep channel in the wood. They are formed at the secondary spark gap of a coil. The terminals are pointed and are under control, so that the gap may be changed in length. To start the balls, the pointed terminals are put upon the wood surface, so near that the surface carbonizes somewhat, after which the gap is made longer. These balls travel in either direction, when a direct current is used with a Wehnelt interrupter. This differs from the results reached on the photographic film with the Holtz machine. There the balls came from the cathode. Even when they originated at isolated points on the film, they traveled away from the cathode.

In the present results, the balls have been caused to orig-

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* This address was printed in full in Science. n. s. **13**: 803–9. 1901.

inate at isolated points, and two balls have started in opposite directions. Wood which gives little flame shows the phenomenon to best advantage, but the balls preserve their identity and travel slowly along even when completely surrounded by flames of the burning wood.

Messrs. George G. Brimmer and J. E. Dame, of St. Louis, and Mr. Ernest J. Palmer, of Webb City, Missouri, were elected to active membership.

One person was proposed for active membership.

April 1, 1901.

President Engler in the chair, thirty-three persons present.

On behalf of a committee appointed at a previous meeting to take suitable action on the death of the late Judge Nathaniel Holmes, a charter member of the Academy, the following memorial was read, adopted and ordered recorded in the minutes: —

Judge Nathaniel Holmes, for many years a valued member of the Academy of Science of St. Louis, died at his home in Cambridge, Mass., March 1, 1901.

He was born in Peterborough, New Hampshire, January 2, 1815. He was a graduate of Harvard of the class of 1837. In 1839 he was admitted to the bar, and later he established himself in St. Louis. In 1846 he was Circuit Attorney. His name appears in the list of charter members of the Academy, and at the first regular meeting on March 10, 1856, he was of the committee which reported a constitution and by-laws for the government of the Academy. At this meeting he was chosen Second Vice-President, and a member of the Council. At the January meeting the next year, he was chosen Corresponding Secretary. This position he continued to hold almost continuously until 1883, when he retired from the practice of his profession and removed to Cambridge, Mass.

During 1866 and 1867, while acting as judge of the Supreme Court of Missouri, he was relieved of the duties of Corresponding Secretary, but he then served as Second Vice-President, and the frequency with which his name appears in the proceedings indicates that he even then took an active part in the work of the Academy. From 1868 to 1873 he acted as Royall Professor of Law at the Harvard Law School. On his return to St. Louis he resumed his services to the Academy, and during the next ten years he was untiring in his efforts in its behalf. He was not himself a worker in science, but he followed the work of others in this country and abroad with the greatest interest. He was particularly and from the first interested in the ideas of Darwin and the evolutionists who followed him.

In the early years of its life he did a great service to the Academy by putting it in communication with foreign societies of learning, and securing an exchange of publications, although the Academy had little to offer. The result was the accumulation of the valuable library of science now owned by the Academy, and which, even in his day, was a thing of which St. Louis might well be proud. He always examined all of our exchanges as they were received, and at each meeting he made a report to the Academy, outlining the ground covered by the more important works, and giving a general summary of the results reached. We still have on our order of business the Report of the Corresponding Secretary, which dates back to his time.

During the Civil War and the years which followed, the interest of the public in the work of the Academy was at a low ebb. He was one of the few citizens of St. Louis whose constant presence at the meetings gave assurance that there was still hope.

Your committee to whom was referred the taking of suitable action in commemoration of his services to the Academy feel that we owe to him and to those who labored with him a debt of gratitude which we can only compensate by actively continuing the work which he and his companions so worthily began.

Francis E Nipher.
Enno Sander.
G. Baumgarten.

The Secretary reported that Dr. Amos Sawyer had presented to the Museum of the Academy the specimens and sketches used in illustration of his communication on Ethnographic life lines left by a prehistoric race, presented at the meeting of March 4, 1901.

Mr John S. Thurman delivered an interesting address on the many industrial uses now made of compressed air, illustrating his remarks by apparatus in operation, including electric motor air compressor, compressed air auger, drill, disinfecting atomizer, sculptors' and stone-cutters' tools, carpet renovators, etc., and a set of lantern slides showing the practical uses made of these and other implements and machines operated by means of compressed air.

Dr. Theodore Kodis exhibited, under the microscope, slides illustrating a new method of staining brain tissue, whereby, in four or five days, it has proved possible to prepare single or double stained preparations containing nerve cells with the dendrides of the latter brought out by a direct stain, instead of being differentiated merely as amorphous silhouettes, as is the case with the much slower Golgi process commonly employed. It was stated that the material is treated before sectioning, for about twenty-four hours, with cyanide of mercury, followed for approximately the same length of time by a formaldehyde solution, after which sections are cut, stained with phosphomolybdate haematoxylin and, if desired, a contrasting stain, such as one of the aniline greens, and mounted in the usual way.

April 15, 1901.

President Engler in the chair, thirty-two persons present.

The Council reported that the Société Scientifique et Médicale de l'Ouest, of Rennes, France, had been added to the exchange list of the Academy.

Professor F. E. Nipher presented by title a paper On the relation of direct to reversed photographic pictures, which on motion was referred to the Council.

Professor C. F. Marbut delivered an address on The advance made in geology during the nineteenth century. The speaker discussed the earlier attempts to explain the structure of the earth, describing the work of Weber, Hutton, Lyell and Cuvier in establishing the chronological scale in general acceptance to-day. The origin of volcanoes, the folding of the earth's crust, the formation of mountains and the study of the rocks were among the topics treated.

Professor C. M. Woodward spoke of An easy method of determining the length of a generation. The speaker observed that the average length of human life is often assumed to be what is meant by a generation, but that it is quite a different thing. The average length of human life in a given community is readily found by averaging the ages of those who die. The statistics for this purpose are given in mortuary reports. He had calculated that average from the Annual Report of the Board of Health of St. Louis, and had found it to be between twenty and twenty-one years. The length of a generation is the average difference in age between father and son; and it is at once evident that this difference is equally independent of child mortality and of longevity. Social and race conditions largely determine the marriageable age and hence the length of a generation. The length of life depends upon race, climate, sanitary regulations, medical science, etc. The schedules of the United States Census contain all the data necessary for determining the length of a generation, as the ages of fathers and sons are given in such proximity that the relationship is obvious. From a few examples the speaker had found the length of a generation of males to be about thirty-two years. For females, that is mother and daughter, it is less than thirty years.

Professor Nipher discussed in brief the latest results of his work on direct and reversed photographs as embodied in his paper presented for publication.

Mr. Benjamin C. Adkins, of St. Louis, was elected to active membership.

One person was proposed for active membership.

May 6, 1901.

President Engler in the chair, twenty-two persons present.

The Council reported that exchange relations with the Cambridge Entomological Club had been discontinued.

The Corresponding Secretary read a letter from Mr. Pierre Chouteau, acknowledging the receipt of the memorial of the late Charles P. Chouteau, adopted by the Academy. The Corresponding Secretary also read a letter from Mr. Arthur MacDonald, requesting the Academy's indorsement of the proposed establishment, under the Department of the Interior, of a psycho-physical laboratory for medico-sociological purposes. This was referred to the Council. The Corresponding Secretary read a letter from Dr. Amos Sawyer, accompanying a peculiar object appearing as if consisting of soapstone and of a dark color, which had been found in the Indian village from which objects exhibited at a recent meeting of the Academy were taken. It was about three inches long, and, a piece having been broken off at one end by accident, it was seen to be hollow within, with an interior core seemingly of hard yellow clay. Dr. Sawyer questioned whether it might possibly have been a plaything of some Indian child.

Mr. C. F. Baker presented an interesting embryological exhibit, consisting of fresh material, dissections, and slides under the microscope, representing the development of the chick during the first forty-eight hours of segmentation. Mr. Baker's purpose in giving the demonstration was to show that with inexpensive apparatus, and inexpensive models, prepared of cardboard and paper, it was within the power of any high school teacher of biology to give a practical knowledge of vertebrate embryology to this extent as a part of the regular laboratory and class-room work.

The secretary presented a letter from Professor Engler, tendering his resignation as President of the Academy, because of his approaching removal from the city, the resignation to go into effect not later than June 15. It being Professor Engler's wish that immediate action should be taken in the matter, the resignation was accepted and the Secretary was instructed to state on the announcement of the next meeting of the Academy that a committee would then be elected to submit nominations for the Presidency of the Academy, in accordance with the provisions of the By-Laws.

Dr. William A. Shoemaker, of St. Louis, was elected to active membership.

One person was proposed for active membership.

May 20, 1901.

President Engler in the chair, twenty-six persons present.

The Council reported that the request of Mr. Arthur MacDonald presented at the last meeting had been declined as not coming within the scope of the Academy, in the judgment of the Council; and the Entomological Society of London had been canceled from the exchange list.

Professor George Lefevre delivered an address on The advance made in zoology during the nineteenth century.

A paper by Professor F. E. Nipher, entitled The specific heat of gaseous nebulae in gravitational contraction, was presented and read by title.

As a committee to nominate a candidate or candidates for the office of President for the remainder of the current year, Messrs. Baumgarten, Green and Alleman were elected.

Mr. Lucian Rosenwald, of Las Vegas, New Mexico, was elected to active membership.

JUNE 3, 1901.

President Engler in the chair, twenty-two persons present.

The nominating committee elected at the last meeting placed Mr. Robert Moore in nomination for the vacant office of President of the Academy for the remainder of the current year, and on motion the Secretary was instructed to issue the ballots for this special election not later than June 5, and to state that the polls would close at six p. m., June 15.

The following papers were presented by title and referred to the Council: —

The action of alcohol on certain isomeric diazo-compounds, by Dr. Gellert Alleman.

A revision of the Blastoideae, by Dr. G. Hambach.

Mr. Wm. H. Roever read a paper on The effect of the earth's rotation upon falling bodies, in which he showed that a body falling from a great height has a southward deviation in the northern hemisphere and a northward deviation in the southern hemisphere. The deviation is given by the formula —

$$\Delta = h\left[\frac{\left(1+\frac{h}{R}\right)^3 K\sin\phi\cos\phi}{1-\left(1+\frac{h}{R}\right)^3 K\cos^2\phi} - \frac{1}{\left(1+\frac{h}{R}\right)}\cdot\frac{K\sin\phi\cos\phi}{1-K\cos^2\phi}\right],$$

in which h is the height through which the body falls, R the radius of the earth (assumed spherical), ϕ the latitude of the place of observation, K the numerical fraction $\frac{1}{289}$ and Δ the deviation. If h and R are given in feet, Δ is in feet.

For $h = 578$ feet and $\phi = 45$, $\Delta = .00133$ inch.

Mr. G. Pauls presented a number of specimens collected at Eureka, Missouri. He exhibited a large number of galls on hickory, maple and oak leaves, commenting on the remarkable variety of the forms of galls made by the minute insects. He had bred a good many of these insects, and found that in successive years a good many different forms came from the galls.

October 21, 1901.

Dr. Green was elected chairman pro tem. About forty-five persons were present.

The Council reported that on a report of the nominating committee, 156 ballots having been cast, Mr. Robert Moore had in June been declared elected President of the Academy for the remainder of the current year; that the Academy had been represented at a meeting of representatives of various bodies called by the President of the Missouri Historical Society to take steps toward securing a permanent home for the Academy and other bodies; that through the death of Colonel George E. Leighton, Mr. Edward Walsh, Jr., Dr. E. S. Lemoine, and Mr. Adolph Herthel, the Academy had lost four members; and that the names of Messrs. J. M. Coulter, F. M. Hugunin, E. T. Jester, and G. H. Pegram had been removed from the list of members.

Professor F. E. Nipher delivered an address of popular and technical as well as scientific interest on Progress made in physics during the nineteenth century.

Mr. G. Pauls exhibited a number of varieties of grapes cultivated by him, among them a seedling of superior value, the Dora, and a large suite of specimens illustrating the coloring of autumnal foliage.

A communication from a committee representing the Missouri Historical Society and other bodies was read, requesting action by the Academy, and on motion the following preamble and resolutions were unanimously adopted: —

Whereas, It is understood that an effort is being made to secure, among the buildings needed for the Louisiana Purchase Exposition, one of fire-proof material, suitably located, and to be used after the Exposition for the housing in an accessible and instructive manner of the libraries and collections of the Missouri Historical Society, The Academy of Science of St. Louis, and other organizations devoted to history, archaeology, natural history and other pure and applied sciences, and for meeting places for such organizations, *Resolved,* That The Academy of Science of St. Louis is heartily in favor of such effort and indorses the proposed ends, which it believes are in the best interest of the community at large.

Resolved, further, That a committee of three be appointed by the chair without delay, authorized to represent this body, in connection with similar committees appointed by other organizations, in such action as may be necessary to secure the desired end.

Two persons were proposed for active membership.

November 4, 1901.

President Moore in the chair, twenty persons present.

The Council reported the resignation of Mr. N. O. Nelson.

Professor A. S. Chessin addressed the Academy On the motion of a top, taking into account the rotation of the earth, giving an abstract of his researches on the earth's rotation as manifested in the motion of bodies on its surface, the details of which he hoped to present shortly in a series of papers.

Dr. B. Meade Bolton and Professor Alexander S. Chessin, of St. Louis, were elected to active membership.

One person was proposed for active membership.

November 18, 1901.

President Moore in the chair, twenty-four persons present.

Mr. G. Pauls presented to the museum a large Favosite fossil from the vicinity of Eureka, Missouri, and a package of cuttings of the Dora grape for distribution among members of the Academy.

The following papers were presented by title: —

F. C. Baker, Some interesting molluscan monstrosities.

Stuart Weller, Kinderhook faunal studies. III. The faunas of beds No. 3 to No. 7 at Burlington, Iowa.

Professor William Trelease read an untechnical address on The progress made in botany during the nineteenth century, which on motion was referred to the Council for publication.

Dr. Martin F. Engman, of St. Louis, was elected to active membership.

December 2, 1901.

President Moore in the chair, eighteen persons present.

Mr. J. Arthur Harris presented in abstract a paper on Normal and teratological thorns of *Gleditschia triacanthos*, L.

Professor A. S. Chessin delivered an interesting address on The harmony of tone and color. The speaker said that although the idea is not new that colors, like tones, are subject to laws of harmony, he did not know that any systematic theory concerning this had thus far been presented, and the object of the paper was to establish such a theory. A color-scale was constructed and the properties of the intervals corresponding to those appearing in the musical scale were discussed, and the conclusion was reached that within the limit of an octave the laws of harmony in tone and color are identical.

A paper by Professor A. S. Chessin, on The true potential of the force of gravity, was presented and read by title, the author remarking that this was the first of a series of detailed papers bearing upon the general subject, the broad conclusions concerning which he had presented in synopsis at a recent meeting of the Academy.

In accordance with the By-Laws of the Academy, a committee, which consisted of Messrs. Green, Evers and Nipher, was elected to nominate officers for the year 1902.

December 16, 1901.

President Moore in the chair, twelve persons present.

The nominating committee reported the following list of candidates for the year 1902: —

President	Henry W. Eliot.
First Vice-President	D. S. H. Smith.
Second Vice-President	William E. Guy.
Recording Secretary	William Trelease.
Corresponding Secretary	Ernest P. Olshausen.
Treasurer	Enno Sander.
Librarian	G. Hambach.
Curators	G. Hambach,
	Julius Hurter,
	Hermann von Schrenk.
Directors	Amand Ravold.
	Adolf Alt.

The Secretary stated that he had received, too late for the information of the nominating committee, a letter from Dr. Smith, asking that his name be not placed in nomination for office, and that, believing Dr. Smith to really desire to be excused, he wished to place in nomination for the office of First-Vice-President Dr. M. H. Post.

A paper by K. K. Mackenzie and B. F. Bush, entitled The Lespedezas of Missouri, was presented and read by title.

Professor F. L. Soldan delivered an interesting address on The advance made in education during the nineteenth century, stating that the most characteristic feature of the century's progress lay in the epoch of expansion and organization which it marked. The influence of Pestalozzi, Froebel, Horace Mann, William T. Harris and other distinguished educators was traced, the marked change in opinion concerning the commercial value of education brought out by the Centennial Exposition of 1876 was indicated, and the establishment of a true university grade in this country with the opening of the Johns Hopkins University, the year following, was commented on.

Professor F. E. Nipher stated that he had continued his experiments on the production of ether disturbances by explosions, and by the motion of masses of matter. He had apparently succeeded in eliminating the effects of the shock of the air-wave upon the magnet needle. The needle is adjusted to a condition approaching maximum sensitiveness. There is no iron about the apparatus except what is contained in the needle and in the compensating magnets. The latter are clamped in place so that the structure on which they are mounted may be pounded by a mallet without disturbing the needle. Rowland effects due to convection of electrified particles have also been eliminated. There remains a marked deflection of the needle, seeming to indicate that an ether distortion or wave originates in a sharp and violent explosion. This result is so amazing that it is announced with the statement that the whole subject is yet under the most searching examination. The coherer and the receiver of the telephone are to be used in two wholly different plans of experiment, in one of which the effects along the entire track of a leaden bullet are to be summed up in an alternating current. The results which seem to have been reached are in entire harmony with the well-known experiment of Michelson and Morley, who found that the ether within the building in which they worked was being carried along with the building and with the earth in its orbital motion.

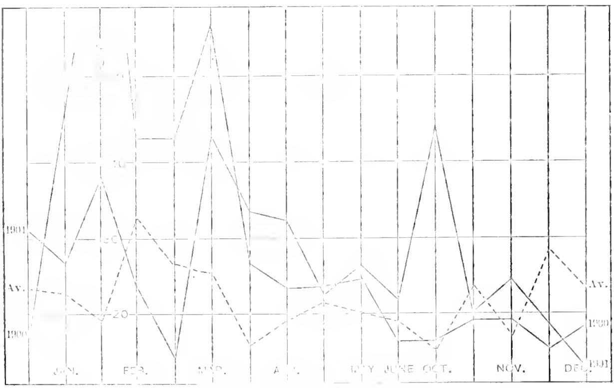
Reports of Officers for the Year 1901.

Submitted January 6, 1902.

The retiring president, Mr. Robert Moore, presented the following address: —

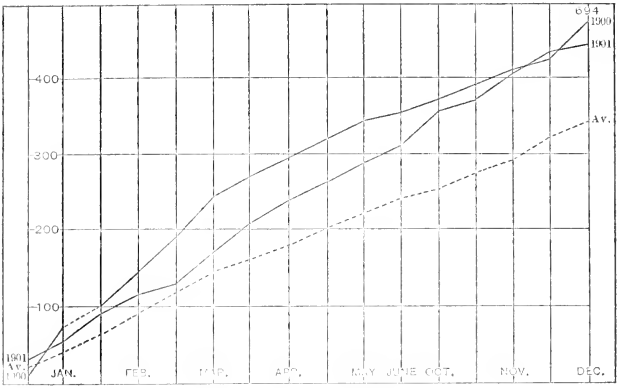
Members of the Academy of Science of St. Louis:

In retiring from the office that since the deeply regretted departure of Prof. Engler from the city has for a few months been occupied by me, it gives me pleasure to record that during the past year the work of the Academy has been carried on with success.



ATTENDANCE BY MEETINGS.

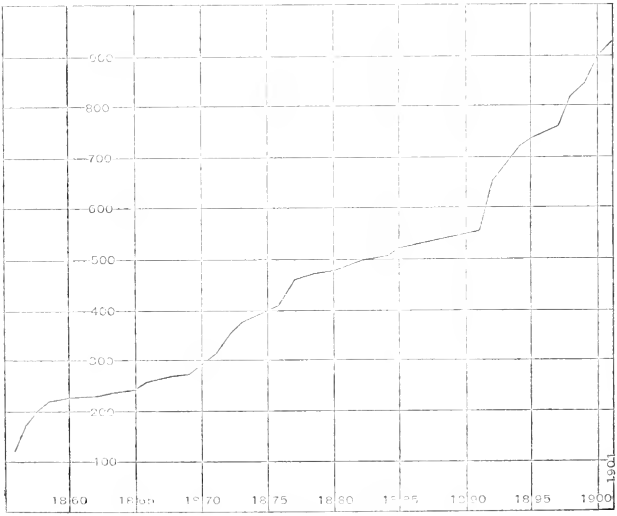
Sixteen meetings have been held with an average attendance of twenty-eight persons. This is somewhat less than during the year 1900, when for reasons of an exceptional nature the attendance for several meetings was unusually large, but it is considerably larger than the average of the five preceding years, 1895–99, and has been more regular than in those years.



ATTENDANCE FOR YEAR.

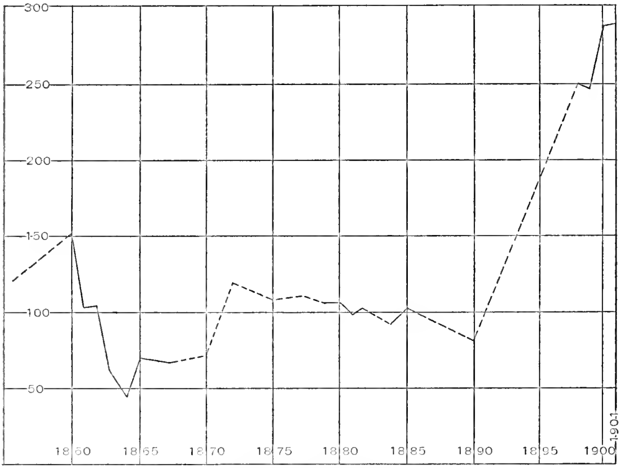
In this we find reason for the belief that the Academy and its work is appealing each year to a larger number of our citizens.

I regret, however, to record that during the past year, the Academy has



TOTAL MEMBERSHIP.

suffered a serious loss in the death of seven members, viz.: Charles P. Chouteau, a charter member, Adolph Herthel, a member of the Council, George E. Leighton, E. S. Lemoine, George A. Madill, Wm. McMillan, and Edward Walsh, Jr., — all honored names whose memories will live long with those who knew them. But notwithstanding our losses from death and other causes we close the year with a roll of membership larger by one than at its beginning. As a contribution to the history of the Academy well worthy of preservation, I submit for publication some diagrams, compiled by the Secretary, showing the attendance at meetings in 1900, 1901, and the average attendance from 1895–9, inclusive, and the membership at different dates since the organization of the Academy in 1856.



ACTUAL MEMBERSHIP.

During the last year the Academy has published ten numbers which with prefatory matter will form the eleventh volume of our Transactions.

The purposes of our organization as stated in the act of incorporation are, the advancement of science and the establishment in St. Louis of a museum and library for the illustration and study of its various branches. In the forty-six years which have elapsed since the Academy was founded it has made important contributions to the advancement of science in many departments, it has made a good beginning in the establishment of a museum, and has collected a library which if it were properly bound and shelved and catalogued might be of very great value to students of science. Our publications go to all parts of the world, and there is hardly any better method of reaching those who are extending the boundaries of knowledge than the pages of our Transactions afford. In a word, the Academy has fully justified the work of its founders and has brought credit to our city.

But with a larger membership and ampler resources how much more might we accomplish for the advancement of science and for the honor of

St. Louis! A brilliant illustration of what can be done by individual effort has been given us during the year that has just closed, during which Mrs. William Bouton has, almost unaided, raised the funds with which to purchase and has given to the Academy one of the best and most beautiful collections of butterflies in the world.

With such an example before us, is it too much to hope that our fiftieth anniversary may be celebrated in a home where amid suitable surroundings our meetings can be held, our library be made accessible and our collections be safely housed? On such a foundation the future of the Academy will be secure as a rallying-point for workers in science and a center for the diffusion of knowledge.

The Treasurer reported as follows: —

RECEIPTS.

Balance from 1900	$ 450 26	
Interested on invested money	285 00	
Membership dues	1,483 00	
		$2,218 26

EXPENDITURES.

Rent	$ 500 00	
Current expenses	430 66	
Publication of Transactions	582 35	
Insurance of property ($10,000 00)	150 00	
Balance to 1902	555 25	
		$2,218 26

INVESTED FUND.

Invested on security	$6,500.00

The Librarian reported that during 1901 exchanges had been received from 287 societies, of which 6 were new. In all, 540 volumes and 481 pamphlets were reported as having been added to the library, an increase of 173 as compared with the preceding year. It was reported that during the year the Transactions of the Academy had been distributed to 561 societies or institutions, chiefly by way of exchange.

PUBLICATIONS.

The following publications of the Academy are offered for sale at the net prices indicated. Applications should be addressed to the Librarian, The Academy of Science of St. Louis, 1600 Locust St., St. Louis, Mo.

TRANSACTIONS (in octavo).

Vol.	Number.	Price per number.	Price per vol.	Price in set.
1	1* 2† 3, 4	.... $4.00 2.00 each.	$7.50 (Nos. 2-4 only.)	$7.00 (Nos. 2-4 only.)
2	1 to 3	2.00 each.	5.50	5.00
3	1 to 4	2.00 each.	7.50	7.00
4	1 to 4	2.00 each.	7.50	7.00
5	1–2, 3–4	4.00 each. (double numbers)	7.50	7.00
6‡	1, 2, 6, 8, 10, 11, 16, 17 4, 5, 7, 13, 14, 15, 18 3, 9 12	25 cts. each. 50 cts. each. 75 cts. each. $1.00	7.50	7.00
7‡	2, 3, 4, 6, 7, 8, 13, 15, 16, 18, 19 5, 9 to 12, 14, 20 17 1	25 cts. each. 50 cts. each. 75 cts. $1.00	7.50	7.00
8‡	1, 3 to 6 8, 10, 12 2, 7, 9, 11	25 cts. each. 50 cts. each.	3.75	3.50
9‡	1, 3, 4, 7, 9 2, 5, 8 6	25 cts. each. 50 cts. each. $1.25	3.75	3.50
10‡	9 2, 4, 5, 10 1 3, 6, 7, 8, 11	10 cts. 25 cts. each. 40 cts. 50 cts. each.	3.75	3.50
11‡	2, 3 5–8, 10, 11 1 4 9	15 cts. each. 25 cts. each. 45 cts. 75 cts. 1.00	3.75	3.50

MEMOIRS (in quarto).

Contributions to the archaeology of Missouri, by the Archaeological Section. Part I. Pottery. 1880. $2.00.

The total eclipse of the sun, January 1, 1889. A report of the observations made by the Washington University Eclipse Party, at Norman, California. 1891. $2.00.

* Supply exhausted.
† Can be sold only to purchasers of the entire volume,—so far as this can be supplied.
‡ Each number is a brochure containing one complete paper (or rarely two).