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DEMONSTRATION OF THE METHOD OF LEAST WORK.

BY WM. CAIN, C. E.; M. AM. SOC. C. E.

1. A new method of ascertaining the stresses in elastic structures by means of the principle of "Least Work" has been elaborated by Castigliano, in his "Théorie de l'Equilibre des Systémes Élastiques" (Turin, 1879), who claims to have given the first complete demonstration of the theorem of least work, though several authors have touched upon it from 1818 to the present time.

In the "Transactions of the American Society of Civil Engineers" for April, 1891, the writer published an article entitled "Determination of the Stresses in Elastic Systems by the Method of Least Work," in which two new and complete demonstrations of the principle of least work are given, both being founded on the well-known principle of "virtual velocities" of mechanics "applied to framed structures."

The following article is an abstract of the briefer demonstration, given in the article by the writer before mentioned, and is based on "the theory of deflections," which will first be given. A few preliminary articles on "elastic work" of a bar in tension or compression, "superfluous" bars in trusses, etc., are added to make the paper sufficiently complete in itself; especially as the aim is to make the demonstrations as simple and elementary as possible.

2. If we call *a* the length of a prismatic bar, *w* its cross section, *e* its modulus of elasticity and *k* its change of length under the stress *s*, then, by the fundamental law of elasticity, when the resultant stress *s* acts along the axis and the limit of elasticity has not been exceeded, we have,

$$k = \frac{a\,s}{e\,w} = c\,s \;.\;.\;.\;.\;.\; (1),$$

if for brevity, we put, $c = \dfrac{a}{e\,w}$.

If the bar lengthens or shortens the amount *k* by the action of a load P, acting in the direction of its axis, which *gradually* increases from 0 to its greatest value P, the stress likewise increases from 0 to its greatest value *s*, and at any instant the stress is exactly equal to the load. If in any small interval of time the average stress is *s*, whilst the length changes an amount *d k*, due to a slight increment of load, the work done is s. d k; therefore as the load changes from 0 to P, the total work done is the limit of the sum,

$$\Sigma\,(s.\ d\,k) = \Sigma\left(\frac{k.\ d\,k}{c}\right),$$

between the extreme values k = 0 and k = k, corresponding to s = 0, and s = s.

∴ *The total work of deformation* for a *gradually applied* load is,

$$\frac{1}{c}\int_0^k k\,d\,k = \frac{1}{c}\,\frac{k^2}{2} = \frac{1}{2}\,c\,s^2 = \frac{1}{2}\,s\,k \;.\;.\;.\;.\; (2);$$

or since load P = s, *work* = ½ *load* × *change of length.*

For a *suddenly applied* load P, causing a change of length k^1 and maximum stress s, the work of the load is P k^1, and since the stress *gradually* increases from 0 to s, the work of deformation, by (2), is $\frac{1}{2}$ s k^1, and since these are equal s = 2 P, or the *maximum* stress is double the load; hence by (1) the change of length is double that for a gradually applied load. After a series of oscillations this change ultimately becomes that due to a gradually applied load and s reduces to P. As, in what follows, we are only concerned with the ultimate or statical stress, we shall always compute *the work of deformation* of a bar, as for a *gradually applied* load, by the formula (2),

$$\frac{1}{2} c s^2 = \frac{1}{2} \frac{a}{e w} s^2 \quad . \; . \; . \; . \; (3).$$

3. *Superfluous bars.* When the figure of a truss has more lines than are strictly necessary to define its form; *i. e.*, to fix its apices when the length of sides are given in order, the extra sides are said to be "*superfluous.*"

The relation between the least number of sides m, or the number of "necessary" bars in a truss and the number of joints or apices n, for *strictly* defining the form of a figure of invariable form, is easily arrived at.

Thus for plane figures (which we shall alone consider in this article) assume the position of one side, thus fixing the two apices at its ends. From these apices we can fix another with two new sides, then another with two new sides from two apices previously fixed, and so on; therefore to each of the (n—2) joints other than the first two corresponds two sides, so that the total number of necessary sides m = 2 (n—2) + 1 = 2 n—3. If the number of sides exceeds (2 n—3), the extra number are "superfluous" to strictly define the form. A less number will give a figure that can change its shape without changing the lengths of its sides.

It is well known that the laws of statics alone suffice to determine the stresses in any truss, whose pieces are free to move at the joints, when the number of bars is just that necessary to strictly determine the form. When there are superfluous bars or continuous members without free play at the joints, the theory of elasticity must be used to give the additional equations, which, added to those furnished by the ordinary laws of statics alone, give as many equations as unknown stresses, from which the latter are obtained by elimination. The theory of "least work" offers a direct solution of such problems.

It may be observed, if a truss is subjected to such *conditions*, that more than two joints are fixed in position, that there may be more bars than are strictly necessary to define the form, even when $m = 2n - 3$. It is always easy in such cases to ascertain the number of "superfluous bars" by supposing the truss built out from two joints taken as fixed, apex by apex, towards the other fixed joints.

The number of bars just sufficient to fix the position of each apex, other than the fixed ones, is easily seen; all other bars are superfluous to this end and must be so treated when applying the method of least work.

4. *Derivative of the Work of Deformation with respect to an external force. Deflection.* Consider a truss of invariable form, without superfluous bars, and let a force unity act in the direction of and along the line of action of any external force P. Then when all the original external forces, such as P, are removed and we have only the force unity acting on the truss, with the corresponding reactions, if any, call u the stress in any bar due to the force unity in question. Also call the length of this bar a, its cross section w and modulus e, and let us conceive it as elongating an amount $\triangle l = \frac{a\,s}{e\,w}$, or the exact amount

caused by the stress *s* due to all the external forces such as P (the force unity being omitted), and that this elongation alone causes the displacement $\triangle p^1$ of force unity in the direction of that force. In applying the principle of virtual velocities we have the right to suppose any displacement $\triangle l$ we choose, and for convenience we take that the bar actually sustains when the truss is fully loaded and not what it would sustain from the force unity.

Now assuming *u* to be tension, the displacements of the ends of the bar are in the opposite directions to the forces acting, so that the virtual velocity is negative. We shall assume the displacement $\triangle p^1$ to be in the direction of the force unity until otherwise ascertained.

We have now by the principle of virtual velocities,

$$1.\ \triangle p^1 - u.\ \triangle l = 0;$$

$$\therefore\ \triangle p^1 = u \frac{a\,s}{e\,w}.$$

If *u* or *s* are compressive, it is evident that they must have the minus sign in the above equation. Should $\triangle p^1$ thus become minus in any case, the displacement will be contrary to the direction of the supposed force unity.

Continuing thus to find the displacement of force 1, due to the change of length of each bar in turn, the other bars remaining unchanged, we have for the total displacement of the force unity, acting in the direction of external force P, the formula,

$$\triangle p = \Sigma \left(u \frac{a\,s}{e\,w} \right) \quad \ldots . \ (4),$$

the sum extending to all the bars of the truss.

But since this displacement is that caused by the actual stresses in all the bars due to the original external forces, it must equal the actual displacement of force P along its direction or the deflection of the truss in the direction of force P.

This is a known formula, by means of which the *deflection* of any truss containing only "necessary" bars in the direction of any given external force or supposed force, can be computed. In using it, strict attention must be paid to the signs of u and s, plus for tension, minus for compression.

We shall now put this formula in a different shape and from it eventually deduce the theory of least work.

If we call X the stress (+ for tension, — for compression) in any bar due to all the loads and their corresponding reactions, when P is omitted, we have the stress in any bar,

$$s = X + u\,P;$$

whence, taking the derivative, since X is entirely independent of P,

$$\frac{d\,s}{d\,P} = u.$$

$$\therefore \quad \Delta\,p = \Sigma\left(\frac{a\,s}{e\,w}.\,\frac{d\,s}{d\,P}\right) = \frac{d}{d\,P}\,\frac{1}{2}\,\Sigma\left(\frac{a\,s^2}{e\,w}\right) \quad \ldots (5),$$

in which it is understood that s must be replaced by $X + u\,P$. Now by eq. (3), $\dfrac{1}{2}\,\dfrac{a\,s^2}{e\,w}$ represents the elastic work of one bar, so that in words (5) shows that *if we express the work of deformation of the bars as a function of the external forces, its derivative with respect to one of the forces gives the displacement, in the direction of the force, of its point of application.*

This is called by Castigliano "the principle of the derivative of work," or it may be termed the theorem of deflection. If we call the work of deformation of the system, F, it is plain, from the above that when $\dfrac{d\,F}{d\,P} = \Delta\,p$ is plus, the displacement is in the direction of the force; when minus, in a contrary direction. When two equal forces, directed both toward or both from each other, along the same line (as in the case of the horizontal thrusts of an arch hinged at the abutments), are designated by the same letter P, if we call P and P^1 the two forces and F the work of deformation of the truss, then $\frac{dF}{dP}$ and $\frac{dF}{dP^1}$ give the actual displacements of P and P^1, along the directions of the forces; both minus or both plus, according as the motion is opposed to the direction of the force or with it; so that $\frac{dF}{dP} + \frac{dF}{dP^1}$ gives the total relative displacements of P and P^1. In case we can regard the apex, at which either force as P^1 acts, as fixed, then $\frac{dF}{dP}$ represents, as usual, the displacement of one apex with respect to the other.

If a truss has *superfluous* members, we can suppose them removed and that two opposed forces act at either end of each bar, each equal to the final stress in the member and acting in the same direction. Then if we designate by P and P^1, the forces replacing the action of any one bar, at either end, upon the apices, then if F represents the work of the necessary bars, $\frac{dF}{dP} + \frac{dF}{dP^1}$ gives the total relative displacement of the apices. Now as we can regard $P^1 = P$ as a function of P, the total derivative of F with respect to P is $\frac{dF}{dP} + \frac{dF}{dP^1}\frac{dP^1}{dP}$; but since $P = P^1$, $\frac{dP^1}{dP} = 1$, therefore *the total derivative of F with respect to P* is equal to

$$\frac{dF}{dP} + \frac{dF}{dP^1};$$

which, from what precedes, is equal to the total relative displacement of the apices, where P and P^1 are applied. Hence, in any case, to find the relative displacement of two apices, between which two equal and opposed forces, P and P^1, act, we have only to take the total derivative of F with respect to one of the forces P, so that it is not necessary to designate the two opposed forces by different letters.

5. Demonstration of the Theorem of Least Work.

Let us suppose that we have a truss of any kind, with superfluous bars numbered n, n + 1, . . . , whilst the (n—1) necessary bars (system N) are numbered consecutively, 1, 2, . . . , (n—1).

Let,

$X_1, X_2, \ldots X_{n-1}$ = stresses in bars 1, 2, . . . , (n—1) of a frame supposed to consist of necessary bars alone (system N) subjected to the actual loading.

$u_1, u_2, \ldots u_{n-1}$ = stresses in bars 1, 2, . . , (n—1) of system N alone, by forces unity acting towards each other from either end of the original position of superfluous bar *n*, all the superfluous bars being removed.

$v_1, v_2, \ldots v_{n-1}$ = stresses in bars 1, 2, . . . , (n—1) of system N alone, caused by forces unity acting towards each other from the apices of superfluous bar (n + 1), all the superfluous bars being removed.

Similarly we proceed for other superfluous bars, if any. The stresses X, *u*, *v*, . . . , can all be found by the laws of statics alone. Now designating the length, cross section and modulus of elasticity of any bar, by *a*, *w* and *e*, respectively, with the same subscript as the number of the bar, we have the total elastic work of deformation of all the bars, including the superfluous bars, expressed by

$$G = \tfrac{1}{2}\,\Sigma\left(\frac{a\,s^2}{e\,w}\right) + \tfrac{1}{2}\,\frac{a_n s_n^{\,2}}{e_n w_n} + \tfrac{1}{2}\,\frac{a_{n+1} s_{n+1}^{\,2}}{e_{n+1} w_{n+1}} + \ldots,$$

in which the sum Σ' extends to the necessary bars alone, or bars 1, 2, . . . (n—1). In this expression it is understood that for *s*, the actual stress in any bar, we must substitute expressions of the type,

$$s = X + u\, s_n + v\, s_{n+1} + \ldots,$$

on supplying the proper subscripts pertaining to the bar considered.

The last expression follows at once from the principle of "superposition of effects."

On designating by F the elastic work of the necessary bars alone, we have

$$F = \tfrac{1}{2}\, \Sigma' \left(\frac{a\, s^2}{e\, w} \right);$$

the sum including only the necessary bars and *s* being expressed as a function of s_n, s_{n+1}, . . , as above.

We shall next regard the superfluous bars n, n + 1, . . . , as temporarily removed and replace their action by two forces for each bar, each equal to the stress in the superfluous bar and acting towards each other, as all bars are assumed to be in tension until otherwise determined.

It has been shown above that treating these forces, s_n, s_{n+1}, . . . , as external forces and *independent of each other*, that $-\dfrac{dF}{ds_n}$ represents the increase in distance between the apices at the extremities of bar *n*, the minus sign being used, since the two forces s_n, s_n, replacing the tension of the bar upon the joints at its ends, act in the opposite direction to the displacements. Similarly for the other deflections. Again, since s_n is supposed to equal the actual stress in bar *n* in the complete structure under the loading, it follows that $-\dfrac{dF}{ds_n}$ must equal the elongation of the bar *n* under the stress s_n when all the superfluous bars are in place, since the real change of length of any superfluous bar n is a necessary consequence of the real changes of length of the necessary bars alone, and it can be found as above, without knowing the changes of length of the superfluous bars beforehand. The increase in distance between the apices at the extremities of superfluous bar n, as determined from "system N," must therefore exactly equal the elongation of bar n under the stress s_n when in place.

$$\therefore -\frac{d\,F}{d\,s_n} = \frac{a_n\,s_n}{e_n\,w_n}$$

or,

$$\frac{d\,F}{d\,s_n} + \frac{a_n\,s_n}{e_n\,w_n} = 0 \;.\;.\;.\;.\;.\;.\;.\; (6).$$

A similar expression obtains for each of the superfluous bars, so that we always have as many equations as there are superfluous bars.

Now each equation of the type above (6), can be found by taking the partial derivatives of the expression for G above, successively with respect to s_n, s_{n+1}, . . . , *treated as independent of each other*, and placing the results separately equal to zero, so that the equations needed will be of the type,

$$\frac{d\,G}{d\,s_n} = 0, \quad \frac{d\,G}{d\,s_{n+1}} = 0, \;.\;.\;.\;.\;.\;.\;.\;.\; (7).$$

From these equations we find, by elimination, s_n, s_{n+1}, . . . , and then substituting these values in equations of the form,

$$s = X + u\,s_n + v\,s_{n+1} + \ldots,$$

we find all the stresses, s_1, s_2, . . . s_{n-1}.

Theorem of Least Work. Therefore, *to determine the unknown stresses, we express the work of deformation of the whole system as a function of the stresses in the bars taken as superfluous, then treating these stresses as independent in the differentiation, we express that the work of* *the necessary bars and one superfluous bar at a time be a minimum; or preferably, that the work of all the bars be a minimum, provided we assume the fiction, that the stresses of the superfluous bars are entirely independent of each other.*

It is this which constitutes the method of "least work."

When there is but one superfluous bar, the true stresses correspond exactly to a minimum of elastic work, but for a greater number of superfluous bars this is not necessarily true, since the stresses in the superfluous bars are functions of each other and not independent, as we assume in forming eqs. (7). This consideration has not been pointed out by any previous author, as far as the writer knows.

The theorems of "deflection" and "least work" have now both been proved by aid of the method of virtual velocities, which, it is seen, is especially adapted to the object in view, as it leads easily and unmistakably to the theorems, and leaves, no doubt, whatsoever as to the exact interpretation of results.

The theorems are easily extended to solid beams, composed of molecules, resisting any change of distance apart by forces varying directly as the changes of distance, according to the law of elasticity first assumed; for such bodies can be treated, therefore, as articulated systems, whence the above theorems directly apply, the unknown stresses between certain molecules taking the place of the stresses in the superfluous bars of the preceding demonstrations. The theorems are therefore perfectly general and apply to solid beams, articulated structures, or combinations of the two, including structures having certain members continuous over certain apices ; but it would take us too far in this article to give the most convenient methods of dealing with such composite structures, which may be found, however, partly in the article by the writer in the April, 1891, Transactions Am. Soc. C. E., and very fully in Castigliano's very exhaustive treatise before mentioned.

ADDITIONS TO THE AVIFAUNA OF NORTH CAROLINA SINCE THE PUBLICATION OF PROF. ATKINSON'S CATALOGUE.

BY J. W. P. SMITHWICK.

1. *Alca torda.* Razor-billed auk. The head, wing and foot of one of this species were sent to the Department of Agriculture, Washington, D. C., for identification by Lieut. Foley, U. S. N. It was taken at Lookout Cove on February 15, 1890. Others were seen. (Auk, April, 1890).

2. *Branta leucopsis.* Barnacle Goose. "Has been taken in North Carolina." (Bul. Am. Mus. Nat. His., Vol. I, No. 7, July, 1886; Allen in "Birds of Massachusetts").

3. *Porzana jamaicensis.* Black Rail. Rare summer visitor in the middle and western sections. Found breeding in both places.

4. *Columbigallina passerina.* Ground Dove. Accidental summer visitor in the mountain region. So far two specimens have been seen and identified. (Cairns).

5. *Archibuteo lagopus sancti-johannis.* American Rough-legged Hawk. Seen occasionally in the winter and spring in the west. (Cairns).

6. *Strix pratincola.* American Barn Owl. One taken at Newport, N. C., by James Moore, Esq., November 7, 1889, and sent to Brimley to mount.

7. *Empidonax flaviventris.* Yellow-bellied Flycatcher. Rare transient in the middle section; one was taken August 11, 1890, in the mountains.

8. *Empidonax pusillus traillii.* Fraill's Flycatcher. One was taken in the mountain region in September, 1889. (Cairns).

9. *Otocoris alpestris praticola.* Prairie Horned Lark. Rare winter visitor in the middle and western sections.

10. *Quisculus quiscula æneus.* Bronzed Grackle. Tolerably common transient in the mountains. (Cairns).

11. *Ammodramus henslowii.* Henslow's Sparrow. One female taken in April, 1890, in the western section. (Cairns).

12. *Ammodramus maritimus.* Seaside Sparrow. One taken by myself, May 15, 1891, in a marsh near Plymouth, N. C. No others were seen.

13. *Chondestes grammacus.* Lark Sparrow. Rare summer visitor at Raleigh. Breeds. (Brimley).

14. *Clivicola riparia.* Bank Swallow. Rare transient in the middle and mountain sections.

15. *Helminthophila bachmani.* Bachman's Warbler. Probably a rare summer visitor. One taken at Raleigh, April 27, 1891. (Brimley).

16. *Helminthophila leucobronchialis.* Brewster's Warbler. Rare transient at Raleigh, N. C. (Brimley).

17. *Dendroica palmarum hypochrysea.* Yellow Palm Warbler. Tolerably common transient at Raleigh, N. C. (Brimley).

18. *Turdus aliciæ.* Gray-cheeked Thrush. Transient visitor, rare at Raleigh; tolerably common in the west.

SANS SOUCI, N. C.

THE ALEXANDER COUNTY METEORIC IRON.

BY S. C. H. BAILEY.

About the year 1875, General T. L. Clingman, of Asheville, presented me with a small piece of meteoric iron, concerning which he was able to give me little information further than that it had been found some years before in

Alexander county, and had been given to him by a Mr. Andrews. The piece was evidently a fragment that had been broken from a larger mass, was rather smoothly rounded upon its broadest surface, and, though wholly devoid of a proper crust, the exterior was quite protected from further oxidation upon that side by the alteration produced from weathering. It did not in any part show any evidence of the pittings common to all classes of meteorites. Its structure is coarsely granular, or made up of polygonal fragments, lightly adherent, with intervening thin folias of Schreibersite and cracks or veins of iron oxide, cementing the mass together. In some instances the Schreibersite also forms small blocks, with rounded outlines. The limited area of the surface cut is only sufficient to show that it belongs to the Braunite type of Meunier, or the "Grobe Lamellen of Brezina." It has a density of 7.635 and its composition, as shown by Venable, is

Iron	91.70
Nickel	5.86
Cobalt	.63
Phosphorus	.095
Oxygen and loss	1.72
	100.00

Where the iron is free from the Schreibersite it cuts easily, takes a good polish, is very light in color, and upon etching it shows neither the Newmann lines nor the figures of Widmanstädt, but it quickly blackens upon applying the acid, and is very slowly corroded. In grains it is quite malleable, but rather brittle in mass. It is most probable that the fragment in my possession came from near the surface of the main mass, and it may present different conditions from the interior portions, which have been protected from the action of the soil or atmosphere. From comparison with examples of the other North Carolina meteoric irons, it is seen to differ essentially from all of them, the only one which it at all resembles being that from "Duel Hill," found in 1873, but several marked differences are apparent upon direct comparison. While the Alexander county was found some years prior to that from Madison county, the places of find are widely apart, and the densities and analyses do not nearly approximate. This iron does not seem to be especially prone to oxidation, and while it belongs to a class that is not very compact in structure, yet the condition of a part of the surface of this specimen above mentioned would indicate that even when denuded of its natural crust its exterior (unless exposed in a very damp soil) would form a new protective coating of oxide which might preserve the parent mass for many years.

Unless it has been so destroyed, the original mass must still be in existence, and as has been the case with other meteorites found in that State, it may now be lying, unrecognized, about some farm building, instead of being where it properly belongs—in the State Cabinet. In a State that has been so favored in the number of its meteoric falls, it would seem to be natural that its people should be alert to gather and preserve these interesting objects. Professor Venable has recently shown that the authenticated fall within the State bears a strikingly large ratio to the entire number of all recorded meteoric falls. The recognition and preservation of the earlier North Carolina meteorites is almost exclusively due to the commendable zeal of General Clingman, and now that the intelligent effort of some of her citizens is directed to the subject it may safely be predicted that the list will soon be much extended.

OSCAWANA ON HUDSON, N. Y., August 19, 1891.

TREATMENT OF ZIRCONS IN PREPARING PURE ZIRCONIUM OXYCHLORIDE.

BY F. P. VENABLE.

Linnemann (Sitz. Ber. Kais. Akad. d. Wissens., Vol. II, 1885, translated in London Chemical News, LII, 233 and 240) has published an account of the "Treatment and Qualitative Composition of Zircons." All previous methods of breaking up the zircon and purifying the zirconia have presented numerous difficulties and proved decidedly unsatisfactory.

Having occasion to prepare some of the compounds of zirconium in considerable quantity and of chemical purity I adopted the methods of Linnemann. In the course of my work I have found it advisable to modify the process in several respects, and I make this publication in order that my experience may be available, and perhaps serviceable, to others.

In the first place, I have found the mechanical preparation can be simplified. I have used North Carolina zircons and have found it sufficient to pulverize them roughly in an iron mortar and then grind in an agate mortar until the powder passed through a 100 mesh sieve. The preliminary exposure during ten days to vapor of hydrofluoric acid and the grinding until the powder passed a silk sieve seemed both unnecessary. The fine powder was repeatedly boiled with strong hydrochloric acid and washed with water. Five hundred grams treated in this way lost seventeen grams, the hydrochloric acid thus dissolving 3.40 per cent. of the whole. The fusions were made in nickel crucibles, which are very much cheaper and less attacked than the silver recommended by Linnemann. The loss comes chiefly in the cracking of the crucibles during the cooling after fusion. The crucibles used measured 10.5 c. m. in diameter by 8 c. m. in height and held a charge of 100 grams zircon, 400 grams sodium hydroxide and 20 grams sodium fluoride. This is one-half the amount of sodium fluoride recommended by Linnemann, but proved sufficient. The sodium fluoride should be dried beforehand. The sodium hydroxide is first thoroughly melted and the fluoride then added. The mass should be brought to a fairly high temperature and then the zircon powder added. A rapid evolution of gas follows the introduction of the powder. The mass should be well stirred by means of a nickel stirrer—a narrow strip of sheet nickel fastened to a glass rod answers the purpose and keeps the hands beyond the reach of hot alkali occasionally thrown out. If the bubbles threaten to rise over the edge temporary removal of the lamp secures their subsidence. The crucible should not be allowed to cool too far, however. Much seems to depend upon carrying through the reaction rapidly at a high temperature. I have at times doubled and even tripled the length of fusion at a lower temperature without securing the thorough breaking up of the zircon secured at a higher temperature. After the first violent boiling a quieter period follows. The end of the reaction is shown by a thickening of the mass and the rising of large bubbles here and there, also sometimes by a fine spitting or spray. In several instances where weights were kept the undissolved or unattacked portion of the zircon powder amounted to less than five per cent.

The melted mass was poured out upon pieces of sheet nickel for cooling. After solidifying enough to handle with tongs it was broken off and plunged in a beaker of cold water. Water was also put in the crucible after it had cooled, to dissolve off the portions adhering to the sides.

The water separates the sodium silicate from sodium zirconate, leaving the latter undissolved. This is dissolved in dilute hydrochloric acid and evaporated several times to dryness with fresh amounts of acid in order to drive off the hydrofluoric acid. The separation by means of water is far from perfect, some of the zirconate going into solution, though not enough, usually, to make it worth while to attempt to regain it. There is a good deal of silica left with the undissolved portion. This is separated after evaporation to dryness. The dried mass is reached with dilute hydrochloric acid. There is difficulty sometimes in extracting all of the zirconium chloride in this way. Of course the solution contains large quantities of salt, besides other substances. Zirconium hydroxide is precipitated away from these by ammonium hydroxide, and then thoroughly washed in large jars by decantation. The crude zirconium hydroxide is next dissolved in strong hot hydrochloric acid, using as small an amount as possible. This solution is evaporated to dryness and the crude zirconium chloride obtained placed in a large funnel and washed with a mixture of strong hydrochloric acid and four parts of alcohol. This mixture is poured upon the mass in the funnel and allowed slowly to drain through. Some zirconium chloride is dissolved, but can be recovered by evaporation. The mass in the funnel is left white and fairly pure. To complete the purification this mass is taken and repeatedly crystallized from boiling hydrochloric acid until the acid gives no test for iron, which seems the most persistent among the impurities. I have commonly found it well to repeat this crystallization more than twenty times. The pure oxychloride is gotten in well-formed crystals of glistening whiteness. This method of crystallizing from hydrochloric acid, used by Linnemann, is the only satisfactory one for purifying the zirconium chloride. I have tried the precipitation by hydrogen dioxide, as recommended by Bailey, but the consumption of pure dioxide is very large and a heavy source of expense, and the pentoxide or mixed oxides yielded is not nearly so convenient as the chloride for further working with. The method described above is shorter than the tedious and expensive treatment with hydrochloric acid, alcohol and ether. Judging from an attempt at carrying it out on a small scale, the amount of ether required in purifying the product from a kilo of zircons would be very large indeed.

The modifications in the process have throughout the aim of cheapening and shortening Linnemann's process, and were successful in both directions, at least under the conditions under which I worked.

A qualitative analysis of the different products obtained while thus decomposing the zircon was made under my direction by Mr. John M. Morehead. It differed in several noteworthy particulars from that made by Linnemann. In the first place, the hydrochloric acid used in the preliminary treatment of the zircon powder extracted a large part of the total tin present. Linnemann does not mention tin as occurring in this solution. No lithium was discovered in any of the solutions, nor any bismuth and zinc. The list of elements found by Mr. Morehead is therefore shorter than Linnemann, who reports sixteen. The list found was sodium, potassium, magnesium, calcium, aluminium, iron, lead, tin, uranium, erbium, silicon and zirconium. Undoubtedly a large proportion of these come from foreign matter mixed with the zircons and sifted into the cracks in the crystal, so as not to admit of separation. A number of the rare elements were looked for without finding them. No thorough spectroscopic examination was made, however.

Mr. Morehead also made several quantitative determinations of the iron, silicon and zirconium, resulting as follows:

Per cent. Zirconia	62.82; 62.59; 63.12; 62.80;
Per cent. Silica	34.10; 34.20; 33.52; 34.10;
Per cent. Ferric Oxide	3.29;

or, taking the means,

$$\begin{aligned} Z2\,O_2 &= 62.83 \\ Si\,O_2 &= 33.98 \\ Fe_2\,O_3 &= \underline{\;\;3.29} \\ & \quad 100.10 \end{aligned}$$

It is not right to calculate the iron as all in the oxidized condition, as much of it comes from the iron mortar and can be easily separated with a magnet.

QUANTITATIVE ANALYSIS OF THE ZIRCON.

BY J. M. MOREHEAD.

In the following analysis it was found most convenient to fuse a portion of the zircon by the Linnemann process, as modified in the preceding article, and from that portion to make the determinations of zirconia and iron. For the silica a second portion was fused with sodium hydroxide, without the use of fluoride. Several other modes of fusion were first tried without satisfactory results.

The method recommended by Classen was tried. One gram of the powdered zircon was fused with five grams each of sodium and potassium carbonate. Heating for one and a half hours with the blast lamp failed to effect thorough fusion. The cooled mass was leached out with water, acidified with hydrochloric acid and filtered away from the unattacked residue. This process was repeated four times, fusing in each case with the same weights of carbonates. It was then found that out of the original gram of zircon .36 gram remained undissolved. This method was abandoned.

The method finally used was to fuse one gram of powdered zircon with ten grams of sodium hydroxide in a nickel crucible, the fusion continuing with an ordinary burner for one-half hour, and then with a blast lamp for twenty minutes. The contents were then poured upon a piece of sheet nickel and cooled. During fusion the mass was occasionally stirred with a nickel stirrer, which must be thoroughly dry. The caustic alkali left on the rod rapidly attracts water on cooling. The cooled mass on the sheet nickel is transferred to a beaker of water and the crucible is rinsed into the same. This was acidified with hydrochloric acid, and in one case only was a residue left. This hydrochloric acid solution was evaporated to dryness and the silica determined in the usual way. Treatment with ammonium fluoride and weighing of the residue not volatilized is essential, as a small amount of zirconia was always found with the silica.

For the iron the solution freed from silica was made up to a known volume, definite portions withdrawn, and the iron determined by titration with a potassium permanganate solution.

In determining the zirconia, measured portions of the solutions were taken, rendered nearly alkaline with sodium carbonate (this is best done in the cold solution); sodium acetate was then added and the whole heated to boiling. After boiling ten minutes the main part of the zirconia will be found precipitated. This is filtered out. The filtrate is acidified with acetic acid, again raised to boiling and boiled for twenty-five minutes with sulphuretted hydrogen bubbling through. The nickel, coming from the crucible, is thus precipitated and is filtered off. The filtrate is acidified with hydrochloric acid and boiled until no further smell of sulphur dioxide is noticed. Then precipitate with ammonium hydroxide, wash thoroughly, dry and ignite. From the weight of this last precipitate must be subtracted the known weight of iron present. The sum of the weights of the first precipitate from the sodium acetate, and this last, as corrected, give the amount of zirconia.

The analyses were made from several fusions. The results were as follows:

	Silica.	Zirconia.	Ferric Oxide.	Total.
	34.10	62.82		
	34.20	62.59		
	33.52	63.12	3.285	
	34.10	62.80	3.29	
Mean	33.98	62.83	3.29	100.10

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PERSON HALL, January 16, 1891.

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SIXTIETH MEETING.

PERSON HALL, February 10, 1891.

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4. The Welsbach Lamp. J. M. Morehead.
5. Multiple Telegraphy. J. W. Gore.
6. Koch's Treatment of Tuberculosis. R. H. Whitehead.

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13. A Brief Sketch of the Pea-nut Plant. Gaston Battle.

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LUXEMBOURG—Verein Luxemburger Naturfreunde.

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SOME CERCOSPORÆ FROM ALABAMA.

BY GEO. F. ATKINSON.

The genus *Cercospora Fres.* comprises a great number of species of leaf fungi producing effects in their hosts frequently termed, in common parlance, "blight," or "leaf blight." The species are all probably more or less parasitic, varying in different degrees of intensity, as obligate parasites, from the forms occurring in dying parts of leaves, languid leaves, upon plants physiologically diseased or of low vitality, induced sometimes by overcrowding and thus preventing necessary circulation of air among the parts or entrance of sunlight; at other times through imperfect assimilation caused by defective drainage, careless preparation and care of the soil, so that the unfavorable physical condition of the soil prevents proper nutrition; by impoverished soil which predisposes the plant to a hastened and unnatural maturity: to perhaps a few cases of a more virulent nature where quite healthy plants are injured from their attacks.

The nature of this parasitism, in general as above described, would suggest to the thoughtful and progressive cultivator of the soil the necessary remedy in each case.

The genus belongs to one of the great groups of fungi known as the *Hyphomycetes.* Its members, along with many others, are sometimes termed "imperfect fungi," because they are not *autonomous; i. e.*, they represent, as is supposed, not complete individuals in themselves, but only a transitory form, or stage, of a polymorphic fungus, the perfect condition of the individual being some species of *Sphærella* or other ascomycetous fungus. Thus they stand only as the conidial stage of more or less complex life cycles. It is quite probable that in this respect they are analogous to other conidial forms, of the nature of which we have more positive knowledge, for example the Powdery mildews (*Erysipheæ*), Downy mildews (Peronosporeæ), etc., so that the conidial stage can reproduce itself successively for several generations without the intervention of the perfect, or ascigerous, stage. Therefore there is not a true, or strictly obligate, alternation of generations such as obtains in the *Muscineæ*, *Filices*, etc.

In but few of the species has the perfect stage been discovered. The writer has given an account of the perfect stage of *Cercospora gossypina* in the Bulletin of the Torrey Botanical Club, Vol. XVIII, p. 300 (*Sphærella gossypina* Atkinson). Pammel (Bulletin No. 13, Iowa Agr. Exp. Sta., May, 1891) is of the opinion that *Cercospora angulata*, on currants and gooseberries, is connected with *Sphærella Grossulariæ*, and that *Septoria Ribis* is also connected with the same perfect fungus. If this should be confirmed, then we have here a *Cercospora* forming one of the stages of a trimorphic fungus possessing conidial, spermogonial, and ascigerous stages. *Cercospora ariæ* Fkl. is considered the conidial stage of *Sphærella cinerascens* Fkl., and *C. radiata* Fkl. of *S. Vulneriæ* Fkl. (Sacc. Syl. Fung., Vol. I, pp. 493, 503). Probably one reason why the perfect stage of but few has been found lies in the fact that in many cases this stage is only developed after the leaves have fallen to the ground and become more or less disorganized or fragmentary and the evidences of the *Cercospora* have disappeared.

While the species are not autonomous, and we thus possess only fragmentary evidence, as it were, of the characters of the complete individual, the peculiarities of form, grouping, markings, color, dimensions and effect upon their hosts are such as to offer comparatively satisfactory data for the systematist to characterize and arrange them. It is fortunate that this is so, because of their parasitic habit it is quite important that we can arrive even approximately at the limitations of the species on the different hosts.

It may seem surprising at first, to one unfamiliar with the growth of these forms and the reactionary influence of their hosts, that so many species are at present known, and that the probability is the number will even yet be increased. The specific physiological differences of the various hosts as well as the structural variations of their leaves, the differences in texture, thickness, and the varying power which the different species possess through their vital processes to resist the growth of the parasite, all exert a powerful influence upon its form and characteristics. Here we have the coincidence of several quite effective agencies, all which tend to produce variations in the parasite. It is quite possible to conceive how during a long period of time a few forms widely distributed over a great number of hosts have become more and more unlike each other and finally more firmly fixed in the possession of peculiar characteristics. This is even more probable when we consider that quite likely during much of this time the hosts themselves have been differentiating more and more so that now well-marked specific differences appear in hosts that long ago were alike and harbored the parasite which has kept pace with them in descent.

The action of the Cercospora parasite on the host results in most cases in the death of the affected part of the leaf, producing a marked appearance in contrast with the unaffected portions, usually termed a "spot." One or more of these spots occur on a leaf, their form varying from circular to angular, or irregular to very indefinite. In many cases the resulting color changes, due to a partial disorganization of the chlorophyl, to a development of erythrophyl or other coloring substances, gives variety to the circumference of the diseased areas or to surfaces of the leaf opposite that on which the fungus is located. In a number of cases there are no well defined spots, but the fungus is diffused over small or large areas of leaf surface, giving to those areas the characteristic color peculiar to the species, being roseate in *C. effusa* (B. & C.) Ell., ferrugineous in *C. lateritia* Ell. and Hal., etc. In the case of *C. catenospora* Atkinson the fungus is diffused over large areas of leaf surface and quite injurious, producing a decided "leaf curl."

The vegetive portion of the fungus consists for the most part of colorless mycelium made up of filamentous, septate bodies irregularly interlaced among themselves and the cells on the interior of the diseased portions of the host. These contain protoplasm, they grow by longitudinal extension and division of their end cells and by branching. Further formation of cells probably takes place by the division of older cells. Their nourishment is obtained by absorbing materials from the cells of their host.

Following the vegetive condition is the conidial stage. Provision is made for the production of conidia and their easy dissemination by means of specialized fungus threads, or fruiting hyphæ, properly *conidiophores*, usually termed briefly by systematists *hyphæ*. These arise in more or less divergent or compact fascicles, which stand perpendicularly to the leaf surface and project beyond it. In a few cases some of the vegetive threads ramify on the surface of the leaf and produce conidiophores in a diffuse manner. The fascicles, or tufts, of conidiophores arise from a more or less compact fungus body termed a *stroma*. This is formed at various points on the vegetive mycelium within the leaf tissue by a lateral growth of certain of the cells together with a conjunction of cells of adjacent threads. In *C. Bœhmeriæ* Pk. this consists of a prominent globose body; from this there are different degrees of compactness and rotundity down to a few closely associated cells which bear only a few conidiophores.

The conidiophores themselves vary greatly in length, size, general direction, markings and color. They may be continuous, septate, geniculate, flexuous, toothed, or cylindrical. The geniculations, the denticulation and much of the flexuous condition is brought about by the manner of growth of the conidiophore while it is bearing conidia. In nearly all the species the conidia are, as termed in some cases, lateral and acrogenous in their production on the conidiophores; *i. e.*, they are borne both laterally and terminally. This is not, strictly speaking, true, but only appears so to be after several conidia have been produced from a single conidiophore. Probably all of the conidia are primarily acrogenous and only later appear to be lateral after the conidiophore has grown at one side beyond the apex on which the conidium was developed. If the conidiophore is growing very rapidly the new growth, which pushes out at one side of the apex on which the conidium is situated, will extend to a considerable distance before another conidium is borne at the new apex. This again grows out past the new conidium, and so on. If the new growth of the conidiophore has been quite divergent from its primary direction a geniculation, or abrupt bend, will appear at the point where the conidium was attached. After the second conidium is borne the conidiophore will usually diverge in a different or opposite direction, giving a somewhat zigzag appearance. At each one of these angles will be a scar left by the abscised conidium. If the onward growth of the conidiophore is not divergent, but follows its primary direction, then a shoulder will frequently appear where the conidium was abscised, or the new growth may occur so soon as to turn the apex with its scar to one side, when the conidiophore will be nearly cylindrical with scars distributed along its sides. In some cases like the latter the production of conidia is very rapid also, so that no sooner has the conidiophore begun to grow past the conidium than it bears another conidium, and thus two or more scars may be left very near each other on a cylindrical conidiophore. If several conidia are thus borne very near one place the conidiophore is apt to be somewhat enlarged at this point, especially if it is characteristic for the species that the scar is left on a minute protuberance. A case of this kind has come under my notice in *C. papillosa* Atkinson. When the growth of the conidiophore beyond its fruiting apex is not very rapid and at the same time in a direction divergent from its primary direction it will appear denticulate or jagged.

The conidiophores are farther marked by *vacuoles* or *guttulæ* in some cases, as well as by the possession of some coloring substance, brown, reddish, olive, fuliginous, etc.

The conidia are usually elongated and filamentous, hyaline or colored, usually septate, cylindrical, terete, obclavate, or tereti-fusoid. In their early development from the apex of the conidiophore they are marked off from the latter by a strong constriction, the union between the two being quite frail. If it does not meet with any mishap it continues to grow by elongation, receiving its nutrition through the small point of contact with the conidiophore. At first it appears as a small oval or elliptical or clavate body, which as it grows elongates, loses it clavate form, and assumes one of the forms described above. The great variation in length of the conidia of the same species is influenced partly by the length of time during which it remains in communication with the conidiophore, but probably more by the climatic conditions, rainy, or damp, weather conducing to a very long growth. Even when conidia are separated from the conidiophores and placed under suitable conditions for germination they will frequently increase in length by apical growth or extension.

The conidia germinate readily in an abundance of moisture, a germ tube being put forth by any or all the cells. In my observations, and they have extended over several species, usually the cell first to produce a germ tube is the basal cell, and the primary direction of this tube is in a line parallel with that of the conidium but in an opposite direction from the apex. This is not universal, but occurs in such a great majority of cases as to be worthy of note. Since writing the above, in examining conidia of *Cercospora Petersii* (B. & C.) from Rav. Fung. Am., 166 (*Helminthosporium Petersii* B. & C.), kindly loaned me by Professor B. T. Galloway, I found a conidium which had germinated, a single germ tube from the basal cell was directed in the way mentioned above.

I have made several attempts to grow conidia of *C. gossypina* in nutrient agar, both with and without an infusion of cotton leaves. Mycelium is formed abundantly, which forms a dark olive-brown mass, many of the fungus threads cohering into stout compact strands several millimetres in length, but in no case have conidia been produced in such cultures with me.

Some remarks are necessary here upon one anomalous species described in the present paper, viz., *C. catenospora*. This is the first species of *Cercospora* that has been described with catenulate spores. Confined strictly to the limitations imposed by Saccardo (Vol. IV, pages 381 and 382, of his Sylloge Fungorum) this species would be placed in division C "*conidia catenulate*," and would there constitute a new genus, since it differs too widely from *Sporoschisma* or *Dendryphium* to be placed in those genera. It might with equal propriety be placed as a new genus among the phragmosporous division of the Family *Mucedineæ* (p. 188), near *Ramularia* or *Cercosporella*, the conidiophores being prominent and quite distinct from the conidia. With the exception of this last character it agrees well with *Septocylindrium*. Here we encounter one of the difficulties of the artificial system of classification which exists to a great extent in the arrangement of some of the *Hyphomycetes*, where such genera as *Ramularia* and *Cercosporella* structurally very closely related to *Cercospora* are made to do duty in an entirely different family. If we consider the variation allowed, and justly so I think, in the genus *Ramularia*, where the conidia are either single or catenulate, this species, in all other respects a true *Cercospora*, is properly located in that genus. This variation between catenulate or not catenulate conidia exists in this one species.

The species enumerated and described below have been collected in Alabama during the last two years, mostly in the vicinity of Auburn. For a short time during the summer of 1891, Mr. C. L. Newman was engaged in my laboratory and some of the collections were made by him. I have been greatly aided in the work of collecting material, preparation of notes and determination of host plants by my assistant, Mr. B. M. Duggar. For the determination of some of the more troublesome hosts I am indebted to Dr. Geo. Vasey, Botanist to the Department of Agriculture at Washington, and to Professor S. M. Tracy, Director of the Miss. Agr. Exp. Station.

Of the seventy-nine species enumerated twenty-eight are here described as new and three varieties are added. One European species (*C. cerasella* Sacc.) and one South American (*C. Bolleana* (Thüm) Speg.) are here described for the first time, I believe, in the United States. The latter I reported in the April (1891) number of the Agricultural Journal, Montgomery, Ala. Two species, one credited to Cooke & Ellis and the other to Ellis & Everhart, are, I believe, also described for the first time. One other species is added by reducing *Helminthosporium Petersii* B. & C. to synonymy.

One other species, heretofore described as *Cercospora persica* Sacc. and later as *Cercosporella persica* Sacc. (Fung. Ital., tab. 67; Sylloge Fung., Vol. IV, p. 218), is excluded. During September, 1890, I collected it at Gold Hill and recognized it as a *Fusarium*. It should read *F. persicum* (Sacc.).

The measurements of conidiophores and conidia are given in terms of the micromillimetre.

There are a few references to numbers of specimens collected by Langlois in Louisiana. These specimens were deposited in the herbarium of the Ala. Polyt. Inst. by C. L. Newman, who received them as exchanges.

Mr. J. B. Ellis has kindly favored me with several specimens for comparison and has examined notes and specimens of a few species. Like favors from others are mentioned in connection with the species.

1. CERCOSPORA CERASELLA Sacc. Spots amphigenous, rusty brown, brighter above with dark border, 2—4 *mm.* Hyphæ amphigenous, fasciculate, fascicles clustered in center of spot or in two or three clusters in different places, olive reddish brown, continuous, subgeniculate or dentate toward apex, 30—50 × 3.5—4. Conidia same color but of a lighter shade, obclavate to acuminate, 5—10—septate, guttulate, 40—75 × 3.5—4.5.

I have compared my specimens with No. 16 fascicle 1 of Brioso et Cavara's Funghi Parassiti delle Piante Coltivate od Utile, and they agree in all essential respects except that the spots in the latter are not well defined, but this may be due to the fact that the leaf in the fascicle I have had access to was probably quite well matured and somewhat yellowed when attacked.

On cultivated cherry (ox heart) leaves (*Prunus avium?*) 1835*a*, Gold Hill, September, 1890, Atkinson; 1968, Auburn, July, 13, 1891, Newman.

2. Cercospora Zinniæ E. & M. Spots small, whitish, with broad indefinite dirty brown border, or numerous small white spots in large confluent brown areas. Hyphæ epiphyllous, loosely fasciculate, 40—80 × 4—4, 5, reddish brown, straight or abruptly geniculate and denticulate toward apex, septate. Conidia obclavate, hyaline, multiseptate, 50—100 × 4—4, 5.

On leaves of *Zinnia multiflora,* 2156, Auburn, summer, 1890, Atkinson.

3. Cercospora cercidicola Ell. Spots amphigenous, dark brown to blackish with indefinite border of dirty yellow, suborbicular, veins of leaf prominent, 3—6 *mm.* Hyphæ mostly hypophyllous, fasciculate, lower half closely and compactly parallel, spreading above, where they are subflexuous, subnodose and prominently denticulate, reddish brown, septate and multiguttulate, 70—160 × 4, 5. Conidia faintly colored, obclavate to tereti-fusoid, 1—5 septate, guttulate, 30—50 × 5—6.

Agrees with N. A. F. 1246, but spots of the latter are darker bordered; the raised border seems to be due to the prominent veins which frequently limit the areas.

On leaves of *Cercis Canadensis*, 2016, Auburn, August 7, 1891, Newman and Duggar.

4. Cercospora omphakodes E. & Holw. Spots brown, black bordered, circular, 2—3 *mm.* Hyphæ amphigenous, fasciculate, subgeniculate and denticulate, bright reddish brown, 30—60 × 4. Conidia slender, terete, dilutely reddish, 4—6 septate, 50—60 × 3.

On leaves of *Phlox Floridana*, 1190, Auburn, June 23, 1890, Atkinson.

5. CERCOSPORA PERSONATA (B. & C.) Ell. Spots amphigenous, circular, dark brown, ususally darker below, frequently arched below, 2—4 *mm*. Hyphæ mostly hypophyllous, frequently also epiphyllous, densely fasciculate, reddish brown, usually short and continuous, toothed, or 50—70 long, septate and subgeniculate 5—7 in diameter. Conidia obclavate, 30—50 × 5—7, or up to 70 long, pale olive brown, 3—10—septate. Agrees in all respects with N. A. F. 2480.

On leaves of *Arachis hypogea*, 2157, Auburn, September 7, 1891, Atkinson, also collected at Columbia, S. C., November 17, 1888.

6. CERCOSPORA OCCIDENTALIS Cooke. Spots much as in *C. personata*, hyphæ amphigenous, paler than in specimens of *personata*. Conidia vary more, being up to 170 long, paler also in color and frequently cylindrical. The oblong spores are not all uniseptate as stated by Berkely (Grev. III, p. 106) but frequently 3—5 or more septate and the long obclavate ones are multiseptate. Thümen's specimens (1964, *C. personata* var. *Cassiæ* Thüm. Myc. Univ.) also agree with mine, the oblong spores not being one septate, but usually several times septate. I consider it quite distinct from *C. personata*.

On leaves of *Cassia occidentalis*, 1547, Auburn, July, 1890, Atkinson; 2128, Duggar. In the latter the clusters of hyphæ are in small patches or widely diffused, no distinct spots. In this respect all the specimens I have seen differ more or less from those of *C. personata* on *Arachis hypogea*.

7. CERCOSPORA MORICOLA Cke. Spots brown, large, irregular. Hyphæ hypophyllous, fasciculate, few in a cluster, reddish brown, septate, denticulate toward apex, 40—70 × 4, 5—5. Conidia hyaline, long, slender, terete, 10—20—septate, straight or curved, 70—200 × 4.

The leaves are injured by another fungus and the spots cannot be well defined. The conidia are stouter than described by Cooke (Grev. XII, p. 30) and Ellis (Jour. Mycol. I, p. 34) and many times more septate, but the septation of long conidia is very variable. It is probably only a variation of Cooke's species.

8. Cercospora Diodeæ Cke. Spots amphigenous, light brown with narrow raised border bounded by dark brown above, suborbicular or semicircular on edge of leaf. Hyphæ epiphyllous, rarely hypophyllous also, in dense tufts from a tuberculate stroma, short, 10—30 × 4—5, reddish brown, longer ones septate and toothed. Conidia slender, terete, fuscidulous, 3—5—septate, 30—100 × 2, 5—3.

On leaves of *Diodea teres*, 1987, Auburn, July 16, 1891, Duggar and Newman.

9. Cercospora Tephrosiæ n. sp. Spots amphigenous, small, angular or suborbicular, 1—2 *mm.*, elevated, blackish brown. Hyphæ epiphyllous, fasciculate, fascicles crowded, reddish, flexuous or dentate, 50—100 × 4, 5—5. Conidia obclavate, subhyaline and tinge of same color as hyphæ, 5—8—septate, usually straight, 70—130 × 4—4, 5.

On leaves of *Tephrosia hispidula*, 2105, Auburn, September 14, 1891, Atkinson.

10 Cercospora truncatella n. sp. Spots amphigenous, suborbicular, whitish with narrow light brown border, 2—4 *mm.* Hyphæ amphigenous, fasciculate, reddish brown, septate, geniculate or nearly straight, conidial scars distributed along at geniculations, 70—250 × 4, 5. Conidia hyaline, faintly septate, tapering very gradually from truncated base to obtuse apex, rarely rounded at base, 50—150 × 3, 5—4. Very different from *C. fusco-virens.*

On leaves of *Passiflora incarnata*, 2025, Auburn, August 26, 1891, Atkinson.

11. Cercospora Agrostidis n. sp. Spots amphigenous, broadly elliptical, very light brown center with broad bor-

der of dull red brown, 3—5 *mm.* long. Hyphæ amphigenous, loosely fasciculate, tufts irregularly scattered and few in a spot, bright reddish brown, septate, nearly straight to subflexuous and sparingly toothed near apex, 40—65 × 3, 5—4. Conidia hyaline, 1—7—septate, terete, straight or little curved, 10—60 × 2, 5.

On leaves of *Agrostis*, 2036, Auburn, July 23, 1891, Duggar and Newman.

12. CERCOSPORA CITRULLINA Cke. On leaves of watermelon (*Citrullus vulgaris*), 1581, Sept. 3, 1890, Atkinson. Specimens are not now at hand, not having been preserved. It agrees well with Cooke's description (Grev. XII, p. 31). The only notes I have in my record are as follows: "Amphigenous, conidia several times (5—9) septate. Affects leaves near base of stem first and gradually progresses toward other extremity."

13. CERCOSPORA CUCURBITÆ E. & E. Spots suborbicular, amphigenous, subochraceous, then whitish bordered by brown, 2—4 *mm.* Hyphæ epiphyllous, fasciculate, dull olive reddish brown, lighter toward apex, septate, subgeniculate and sparingly toothed or scarred toward apex, 70—200 × 4—4, 5. Conidia hyaline, slender, terete, straight or curved, multiseptate, 50—120—200 × 3—4.

On leaves of "dish-rag" squash, (*Cucurbita?*) 2154*a*, Auburn, 1890, Atkinson; *Lagenaria vulgaris*, 2154, September 10, 1891, Duggar.

This may be identical with *C. citrullina* Cke.

14. CERCOSPORA PACHYSPORA E. & E. Spots amphigenous, dark brown with concentric elevated lines and indefinite yellowish border, suborbicular, 4—10 *mm.* Hyphæ amphigenous, more numerous below, fasciculate, stout, dilutely ochraceous, septate, flexuous, when young nearly hyaline, 50—100 × 5—9. Conidia hyaline or dilutely yellowish, obclavate, 3—8 septate, 25—100 × 8—10.

On leaves of *Peltandra alba*, 2193, Auburn, September 26., 1891, Duggar.

15. CERCOSPORA BETICOLA Sacc. Spots amphigenous, possessing a blistered appearance, grayish with dark border, 1—3 *mm.* Hyphæ fasciculate, cylindrical, fuscidulous, continuous, nodulose or scarred at or near apex, 70—200 × 4—5. Conidia slender, terete, hyaline, multiseptate, 70—140 × 3.

On leaves of cultivated sugar beet (*Beta vulgaris*), 1832, Auburn, November 28, 1890, Atkinson.

16. CERCOSPORA VERNONIÆ E. & K.? Spots amphigenous, dirty greyish brown with irregular, indefinite border, variable in size. Hyphæ epiphyllous, fasciculate, mostly hyaline when young to fuscidulous, subnodose and toothed, 20—40 × 4, 5. Conidia hyaline, obclavate, slender, 3—12—septate, 70—120 × 3, 5—4.

On leaves of *Vernonia noveboracencis*, 2073, Auburn, August 29, 1891, Atkinson.

17. CERCOSPORA FLAGELLARIS E. & M. Spots amphigenous, at first small, whitish, 2—4 *mm.*, with raised and blistered margin, bordered with indefinite red, later larger and often then confluent over dead parts of the leaf and marked frequently with concentric lines. Hyphæ amphigenous, fasciculate, pale reddish brown, septate, nearly cylindrical, undulate and nodulose above, 30—50 × 4, 5. Conidia long, abruptly slender from near the base, hyaline, multiseptate, 30—120 × 4.

On leaves of *Phytolacca decandra*, 1947, Auburn, July 11, 1891, Newman.

18. CERCOSPORA ACALYPHÆ Pk. Spots on leaves amphigenous, small, numerous, with a 1—3 *mm.* white center bordered above by dark purple, below by light brown. Hyphæ amphigenous, loosely fasciculate, nearly straight or subflexuous or geniculate, prominently scarred, septate, olive brown with faint reddish tinge, 80—140 × 4, 5—5.

Conidia hyaline, terete, straight or curved, multiseptate, 50—200 × 3—4. On the stems the spots are elliptical to oblong, dirty white with dark border.

On leaves and stems of *Acalypha caroliniana*, 1998, Auburn, August 6, 1891; 2102, September 12, 1891, Newman.

19. CERCOSPORA POLYGONACEA E. & E. Spots ochraceous; suborbicular, 3—10 *mm.*, parts of the leaf often reddish. Hyphæ amphigenous, fasciculate, tufts numerous in center of spot, scattered toward border, when young faintly fuliginous and nearly cylindrical, in age plainly reddish brown, septate, subflexuous and denticulate, 30—80 × 4, 5. Conidia hyaline, obclavate, straight or curved, faintly septate, 50—100 × 4—5.

On leaves of *Polygonum dumetorum* var. *scandens*, 2225, Auburn, October 14, 1891, Duggar. Specimens were submitted to Ellis.

20. CERCOSPORA LOBELIÆ K. & S. Spots amphigenous, dirty white with dark indefinite purple border, usually small, irregular, 2-6 *mm.* Hyphæ amphigenous, more numerous above, fasciculate from tuberculate base, strongly denticulate, olive brown when young with reddish tinge to reddish brown in age, 10—150 × 4, 5—5, long ones subgeniculate. Conidia faintly colored obclavate, septate and sometimes constricted, 50—100 × 4, 5.

On leaves of *Lobelia amœna*, 2226, Auburn, October 14, 1891, Atkinson. Specimens of this were submitted to Professor Kellerman.

21. CERCOSPORA RHUINA C. & E. Spots amphigenous, above dull reddish brown bordered by black, or entirely black and often with indefinite red border, in age sometimes becoming greyish in center, light brown below, frequently arched upward, with or without a narrow elevated border. Hyphæ densely fasciculate, amphigenous, from tuberculate stroma, dull reddish brown, irregularly flexu-

ous, torulose, or denticulate 30—150 × 3—4. Conidia nearly cylindrical to very narrowly tereti-fusoid, or obclavate, and curved, 3—5—multiseptate, faintly olive—fuscidulous, 25—120 × 3—4.

On leaves of *Rhus copallina*, 1178, Auburn, June 30, 1890, *R. toxicodendron*, 1181, June 30, 1890; *R. venenata*, 1304, Shorter's Station, July 16, 1890; *Rhus* sp. undetermined, 1565, Auburn, August 6, 1890, Atkinson; *Rhus glabra*, 2014, Auburn, August 7, 1891, Duggar and Newman. On *R. toxicodendron* both the hyphæ and conidia are more slender than on the other species, and the conidia longer, many times more septate and very frequently guttulate. The variations, however, considering other very striking resemblances, do not seem sufficient to separate it.

22. Cercospora canescens E. & M. Amphigenous, in large dead areas, or spots 2—6 *mm.*, brown or dirty grey with narrow dark border above. Hyphæ amphigenous, fasciculate, brown, septate, nearly cylindrical, stout, 50—100 × 5. Conidia hyaline, obclavate, 3—8—septate, nearly straight, 30—120 × 4, 5—5, 5.

On leaves of cultivated bean (*Phaseolus vulgaris*), 1983, Auburn, July 25, 1891, Newman.

23. Cercospora avicularis Wint, var. sagittati n. var.? Spots amphigenous, light brown with narrow elevated margin frequently bordered by reddish brown, 2—3 *mm.*, Hyphæ olive brown, frequently with reddish tinge, fasciculate, septate, sometimes subgeniculate to denticulate, 70—170 × 4. Conidia faintly colored, septate, 100—300 × 3, 5.

On leaves of *Polygonum sagittatum*, 2201, Auburn, October 1, 1891, Duggar.

24. Cercospora Liquidambaris C. & E. Spots amphigenous, dirty white above, brown below, small, numerous, irregular with a blistered appearance. Hyphæ fasciculate from tuberculate base, dark reddish brown, short,

flexuous, torulose, septate, and minutely guttulate, 20—100 × 4—4, 5. Conidia subhyaline or tinged with olive, terete, straight or curved, 45—150 × 3, 5—4.

On leaves of *Liquidambar styraciflua*, 2227, Auburn, October 14, 1891, Atkinson. In Jour. Mycol., Vol. IV, p. 115, as a note appended to *C. tuberculans* E. & E., Ellis says: "This is very different from *Cercospora Liquidambaris* C. & E., which is on definite spots." This is the only published notice of the species of which I have any knowledge. Ellis writes me that he does not know whether a description has ever been published, but that there is a specimen in his herbarium marked *C. Liquidambaris* C. & E. This is probably the same as No. 77 of Langlois' collection, of which I have a specimen marked *C. Liquidambaris* E. & E. At first sight it would appear quite different from my specimens, for the spots are brown above, orbicular and quite large. There are, however, numerous whitish, small, blistered spots, and a few of these are changing to brown. I should say that Langlois' specimens were in a more advanced condition than mine. The chief difference in the fungus is that in my specimen the conidia are much longer and more nearly hyaline. This can be accounted for by the fact that I could find no conidia in my specimens until I had placed them for twenty-four hours in a moist chamber, where the conditions were favorable for rapid growth.

25. CERCOSPORA ANTHELMINTICA n. sp. Spots small, amphigenous, 1—3 *mm.*, white with narrow raised margin surrounded by dark border. Hyphæ epiphyllous, fasciculate, spreading, subflexuous, subnodnose and profusely toothed, septate, fuliginous with faint reddish tinge, 30—100 × 4—4, 5. Conidia hyaline, terete, 4—10 septate, 25 100 × 4—4, 5. Different from *C. Chenopodii.*

On leaves of *Chenopodium ambrosioides* var. *anthelminticum*, 2037, Auburn, August 27, 1891, Duggar.

26. Cercospora Jussiææ n. sp. Epiphyllous, small white spots surrounded by indefinite reddish purple border. Hyphæ fasciculate, reddish, septate, geniculate and denticulate toward apex, 40—120 × 4—4, 5. Conidia hyaline, obclavate, 3—10—septate, 100—150 × 4.

On *Jussiæa leptocarpa*, 2159, Auburn, September 2, 1891, Duggar; *J. decurrens*, 2191, Auburn, September 29, 1891, Atkinson.

27. Cercospora fusimaculans n. sp. Spots amphigenous, light brown bordered by dark brown, broadly fusoid or elliptical, 3—4 *mm.* long, frequently confluent. Hyphæ epiphyllous, fasciculate, olive reddish brown, straight, subgeniculate or nodulose, sparingly denticulate toward apex, septate, 50—100 × 4—4, 5. Conidia small, hyaline, 3—4 septate, tapering little toward each end, 25—40 × 2.

On leaves of *Panicum dichotomum*, 2054, Auburn, August 15, 1891, Duggar.

28. Cercospora Setariæ n. sp. Spots amphigenous, dark with indefinite pale border, elliptical. Hyphæ epiphyllous, dull reddish brown, fasciculate, sometimes very dense, others divergent, sometimes branched from near base, septate, with a few small guttulæ, scars small, giving denticulate appearance near apex, 50—100 × 4, 5—5. Conidia hyaline, 1—pluriseptate, cylindrical or obclavate, straight or curved, 20—150 × 4—5.

On leaves of *Setaria glauca*, 2120, Auburn, September 17, 1891, Duggar.

29. Cercospora asterata n. sp. Spots amphigenous, about 6 *mm.* in diameter, generally in edge of leaf, dirty grey bordered by black, exterior to this effused with reddish purple. Hyphæ amphigenous, fasciculate, dull reddish brown, subhyaline at tips, septate, geniculate, subflexuous, torulose to denticulate, minutely guttulate, 70—

$120 \times 4, 5$. Conidia hyaline, nearly cylindrical, tapering gradually to each end, septate, $30—50 \times 3$.

On Aster, 2365, Auburn, November 25, 1891, Atkinson.

30. CERCOSPORA RICHARDIÆCOLA n. sp. Spots amphigenous, black with small white center and concentric lines suborbicular, 2—6 *mm.* Hyphæ epiphyllous, fasciculate, faintly fuliginous when young with reddish tinge, reddish brown in age, usually straight but sometimes geniculate or subflexuous to denticulate toward apex, $10—80 \times 5$. Conidia hyaline, obclavate, 4—10 or more septate, 50—$100 \times 3—4$.

On leaves of *Richardia Africana*, 2111, Auburn, September 7, 1891, Atkinson. Very different from *C. Callæ* Pk. & Clint.

31. CERCOSPORA ALABAMENSIS n. sp. Spots amphigenous, dirty white definitely limited by dark purple or black with raised margin, 2—3 *mm.* Hyphæ amphigenous, loosely fasciculate, fascicles numerous, faintly septate, dilutely reddish brown, nearly straight, denticulate, or abruptly shouldered and prominently scarred at angles, $50—100 \times 4, 5$. Conidia long, slender, straight or curved, hyaline, closely multiseptate, terete, $70—250 \times 3—4$. This is quite different from specimens collected by Prof. Galloway in Missouri, which have been referred by Ellis to *C. Ipomœæ* Winter, and specimens of which have been kindly furnished me by Galloway and Ellis.

On *Ipomœa purpurea*, 1248, Uniontown, July 12, 1890, Atkinson.

32. CERCOSPORA FLAGELLIFERA n. sp. Spots amphigenous, suborbicular to angular 3—4 *mm.* or large and indefinitely limited (this may be due to presence of other fungus), dark brown above, lighter below. Hyphæ amphigenous, rather compactly fasciculate or spreading, reddish brown, prominently scarred and flexuous and denticulate toward tips, or cylindrical, $40—150 \times 4, 5$. Conidia

hyaline, very long and slender, multiseptate, 70—250 × 2, 5—3 at base.

On leaves of *Galactia pilosa*, 2180, Auburn, September 9, 1891, Atkinson; *Lespedeza?* 2117, September 17, 1891, Duggar. The spots are different on *Lespedeza?*, being angular and nearly black above, and rather small, while in *Galactia pilosa* they are quite large and indefinitely limited. The fungus, however, seems to be the same. It is quite different from *C. latens*.

33. Cercospora papillosa n. sp. Spots orbicular or irregular, sometimes in edge of leaf, dirty white, 2—5 *mm*. Hyphæ amphigenous, fasciculate, nearly straight, denticulate to papillate, the scars sometimes being on minute protuberances. In some cases I have seen them several in a whorl, reminding one of the appearance of some sexual shoots of some algæ of the family *Lemaneaceæ*, fuliginous with very faint brick-red tinge, 50—70 × 4, 5—5. Conidia hyaline, long, rather stout at base, usually tapering rather abruptly into slender, thread-like apical portion, multiseptate, sometimes faintly so, 80—200 × 4—4, 5 at base.

On leaves of cultivated *Verbena*, 2376, Auburn, December 24, 1891, Atkinson.

34. Cercospora Hydrangeæ E. & E. Spots large, angular, limited by veins, blackish above, frequently becoming whitish in center, light brown below. Hyphæ amphigenous, fasciculate from tuberculate base, olive brown with dull reddish tinge in age, subgeniculate and denticulate, 40—70 × 4—4, 5. Conidia hyaline, long, slender, terete, curved, multiseptate, 70—150 × 3—4.

On leaves of cultivated *Hydrangea*, 1013, Auburn, 1890, Atkinson. Specimens of this sent over a year ago to Ellis were marked *C. Hydrangeæ* E. & E. I think this is the first published description and Ellis' name is given.

35. CERCOSPORA DESMODII E. & K. Spots small, 2—3 *mm.*, angular, amphigenous, light brown, numerous, frequently confluent. Hyphæ mostly hypophyllous, fasciculate, 4—8 from tuberculate base, light reddish brown, septate, undulate and sometimes geniculate, 40—80 × 4—5. Conidia hyaline, terete, slender, faintly septate, 30—80 × 25—35.

On leaves of *Desmodium*, 1241, Uniontown, July 12, 1890, Atkinson; Cultivated *Desmodium* (Florida clover), Auburn, 1890, Atkinson.

36. CERCOSPORA SOLANICOLA n. sp. Spots small, white, dark border, or indeterminate on dead areas of the leaf. Hyphæ fasciculate, olive brown with faint reddish tinge, straight to flexuous or geniculate toward apex, 3—5 septate, 40—120 × 5. Conidia hyaline, terete, obtuse, 10—30 septate, 100—230 × 4, 5.

On leaves of *Solanum tuberosum*, 1922, Auburn, June 19, 1891, Atkinson.

37. CERCOSPORA GALII E. & Hol. Spots amphigenous, irregular, large, greyish brown. Hyphæ amphigenous, fasciculate from tuberculate stroma, septate, fuliginous, short, 15—20 × 4—5. Conidia straight or flexuous, faintly 1—6 septate, dilutely yellowish, terete, 40—70 × 3—4.

On leaves of *Galium pilosum*, var. *puncticulosum*, 1318, Auburn, July 22, 1890, Atkinson.

38. CERCOSPORA VIOLÆ Sacc. Spots amphigenous, white, 2—6 *mm.*, suborbicular, sometimes confluent. Hyphæ amphigenous, fasciculate, nearly straight, long ones sometimes subflexuous and subdenticulate, fuliginous, sometimes with reddish tinge, 30—70 × 4—5, in rainy weather frequently 150—300 long. Conidia hyaline, long, slender, terete, multiseptate and nearly straight, 100—200 × 3, 5—4.

On leaves of *Viola odorata*, 1946, Auburn, July 25, 1891; *Viola cucullata*, 2372, December 14, 1891, Atkinson.

39. Cercospora nympheacea E. & E. Spots amphigenous, subcircular, 2—4 *mm.*, nearly the entire disk is of a leaden color from profuse development of the fungus, bordering this is a narrow ring of dirty grey color, margined by indefinite purple, which is separated from the grey ring by slightly elevated ring. Hyphæ epiphyllous, densely fasciculate, fascicles crowded, short 10—20 × 3, fuliginous with olive tinge. Conidia very slender, tapering very little toward apex, hyaline or subhyaline, 8—multiseptate, curved or flexuous, 80—120 × 2, 5—3.

On leaves of *Nymphea odorata*, 2160, Auburn, September 2, 1891, Duggar.

40. Cercospora Saururi E. & E. Spots black above, light brown below, suborbicular, 3—6 *mm.*, with a broad, ill-defined border of yellow. Hyphæ amphigenous, fasciculate, short, nearly straight, faintly fuliginous, 10—20 × 4—5. Conidia hyaline, terete, straight or curved, few to pluriseptate, 30—140 × 3, 5—4, 5.

On leaves of *Saururus cernuus*, 1303, Shorter's Station, July 16, 1890, Atkinson.

41. Cercospora Rubi Sacc. Spots amphigenous, brown with frequently a light center, bordered by red above, irregular and frequently confluent. Hyphæ epiphyllous, fasciculate, spreading from tuberculate base, short, continuous, faintly fuliginous, tufts black, numerous, 3, 5—4 in diameter. Conidia acrogenous, terete, slender, faintly colored, 30—100 × 2, 5—3.

On leaves of *Rubus cuneifolius*, 1130, December, 1889; 1536, August 8, 1890; 1764, September 4, 1890, Auburn, Atkinson. In 1536 the red border of the spots is suffused with yellow.

42. Cercospora Bœhmeriæ Pk. Spots amphigenous, at first limited by the veins of the leaf, in age sometimes orbicular with indefinite yellowish border, 3—6 *mm.* Hyphæ hypophyllous from rotund tuberculate stroma,

fuliginous, nodulose, continuous, usually short, up to 50 long by 4—4, 5. Conidia fuliginous with faint olive yellowish tinge, 3—5 septate, guttulate, tapering little toward each end, but more toward apex, 40—75 × 4—4, 5.

On leaves of *Bœhmeria cylindrica*, 2321, November 7, 1891, Auburn, Atkinson. Also collected at Shorter's Station, July 16, 1890. These latter specimens were young and the spots distinctly angular.

43. CERCOSPORA HYDROCOTYLES E. & E. Spots amphigenous, light brown, orbicular, with narrow elevated margin and indefinite border of dark brown, 3—4 *mm.*, somewhat arched upward. Hyphæ amphigenous, fasciculate, tufts evenly distributed, faintly fuliginous, continuous or sometimes faintly septate, straight or subgeniculate to toothed near apex, 30—50 × 4—4, 5. Conidia hyaline or subhyaline, slender, terete, multiseptate, sparingly guttulate, 30—70 × 2, 5—3.

On leaves of *Hydrocotyle umbellata*, 1308, Shorter's Station, July 16, 1890, Atkinson.

44. CERCOSPORA MALI E. & E. Spots amphigenous, light brown below, greyish above, subcircular, 3—4 *mm.* Hyphæ amphigenous, fasciculate from dark tuberculate stroma, very short, fuliginous, 3, 5—4 in diameter. Conidia hyaline, very slender, terete, 3—7—septate, 30—75 × 2, 5—3.

On leaves of *Pirus malus*, Gold Hill, September, 1890, Atkinson. These specimens do not agree very well with N. A. F. 2478, the hyphæ being much shorter and the conidia not colored. The material is scanty and it does not seem best to separate it.

45. CERCOSPORA ELEPHANTOPODIS E. & E. Spots brown with dirty yellowish indefinite border, orbicular, less distinct on under surface. Hyphæ epiphyllous, very short, scarcely raised above the tuberculate stroma, faintly fuliginous. Conidia long, very slender, straight or curved,

pluriseptate, dilutely yellowish, 25—120 × 2, 5—3. This is probably a young stage, since in N. A. F. 1757 the hyphæ are amphigenous and well developed.

On leaves of *Elephantopus tomentosus*, 1179, Auburn, June 30, 1890, Atkinson.

46. Cercospora atramaculans E. & E. Spots amphigenous, suborbicular, 4—8 *mm.*, light brown to nearly black. Hyphæ amphigenous, fasciculate, tufts distributed thickly over the spot, divergent, sometimes branched, subflexuous, irregular in outline, denticulate, septate and guttulate, olive fuliginous with reddish tinge in age, 30—80 × 4. Conidia very narrowly tereti-fusoid, or narrowly lanceolate, 3—10 septate, guttulate, faintly fuliginous, 20—70 × 3, 5—4.

On leaves of *Cassia Tora*, 2129, Auburn, September 10, 1891, Atkinson.

47. Cercospora cruenta Sacc. Spots orbicular mottled by blood-red splotches. Hyphæ amphigenous, fasciculate, tufts distributed over spot, short or quite long, faintly olive fuliginous, not reddish brown when long, as in *C. Dolichi*, septate, flexuous, simple or branched, 40—150 × 4. Conidia faintly olive, frequently guttulate, septate, 40—120 × 4.

On leaves of *Dolichos sinensis*, 1238, July 18, 1890; *Phaseolus* (cultivated), 1236, July 18, 1890, Auburn, Atkinson.

48. Cercospora viticola (Ces.) Sacc. Spots suborbicular with indefinite ragged border, blackish above or brown in center with black border, light brown below, affected parts of leaf outside of the spots frequently changing to yellow. Hyphæ amphigenous, parallel and densely fasciculate in compact column 100—300 long, individual hyphæ septate, free for short distance at distal end where sometimes subclavate, abruptly subflexuous, jagged and denticulate when having borne many conidia, sometimes

divergent at distal end, though not nearly so much so as in *C. cercidicola* and *C. Petersii* (B. & C.), though the sterile part of the fascicle is much more compact than in the latter species. Hyphæ, where compacted into bundle 3, 5—4 in diameter, usually somewhat greater, 4—5, at the free ends, dark olive brown. Conidia obclavate, abruptly tapering at base, usually curved, 3—12 septate, sometimes very distinctly so, same color as the hyphæ, though more dilute, 40—70 × 4—7.

Common on cultivated grape leaves (Vitis), Auburn, Atkinson.

49. CERCOSPORA PETERSII (B. & C.). *Helminthosporium Petersii* B. & C., Grev. III., p. 102 (*ex-parte?*), *Helminthosporium Petersii*, Rav. Fung. Am. Ex., 166. Spots amphigenous, light brown in center, with blackish border, orbicular, 2—3 *mm.* Hyphæ amphigenous, mostly hypophyllous, fasciculate, very dark olive brown to nearly black, septate, 100—300 × 4—4, 5, for about two-thirds their length parallel and quite closely compacted into a bundle, not so much so as in *C. viticola*, distal one-third divergent and very profusely subflexuous, denticulate, torulose, jagged, and diameter somewhat greater than the straight portion. Conidia obclavate or narrowly teretifusoid, abruptly acuminate, resembling in form those of *C. cerasella*, but much darker in color, dark olive brown, 2—6 septate, 30—70, even sometimes to 100 × 5—6 at base.

This is very different from *C. smilacis*, Nos. 1676 and 1768 Myc. Univ., the conidia there being much narrower, the hyphæ shorter and otherwise quite different. It differs also from N. A. F. No. 1251. It also seems to be quite different from Saccardo's description of his *C. smilacina* (l. c.) and the figure in F. Ital., No. 681, but may be identical. I have not seen specimens of Peck's *C. Smilacis* and cannot say whether or not it is the same as this species, but I am inclined to think it is; the spores in a young condition may sometimes be hyaline. Prof. B. T. Galloway, Chief of the Division of Veg. Pathology, has kindly permitted me to examine the specimen of *Helminthosporium Petersii* in Rav. Fung. Am., 166, from *Smilax*. It is identical with my specimens from Alabama. I have no doubt that B. & C.'s specimens on *Smilax* are the same. I have not seen the fungus on *Laurus Benzoin* and I have arranged the synonymy for the specimens on *Smilax*.

On leaves of *Smilax glauca*, 1288, Shorter's Station, July 16, 1890; 2375, Auburn, December 20, 1891, Atkinson.

50. CERCOSPORA LUDWIGIÆ n. sp. Spots amphigenous, subcircular, irregular, reddish brown or purple, sometimes with white in center, 1—3 *mm.* Hyphæ epiphyllous, densely fasciculate from tuberculate base, short, olive brown or faintly fuliginous, straight or flexuous, 20—30 × 4, 5. Conidia slender, terete, straight or curved, sometimes guttulate, 3—10 septate, faintly colored, 25—100 × 2, 5—3.

On leaves of *Ludwigia alternifolia*, 2190, Auburn, September 29, 1891, Atkinson.

51. CERCOSPORA D. VIRGINIANÆ n. sp. Spots amphigenous, brown or dirty white with a broad, ill-defined purple border above, 2—5 *mm.* Hyphæ amphigenous, fasciculate, tufts numerous, fuliginous, nearly straight, denticulate, 40—250 × 4—5. Conidia hyaline, stout at base, tapering to long, slender apical portion, multiseptate, 80—350 × 4.

On leaves of *Diodia virginiana*, 2186, Auburn, September 26, 1891, Duggar.

52. CERCOSPORA CRINOSPORA n. sp. Hyphæ fasciculate, 3—6 in a tuft, undulate, sparingly toothed and nearly hyaline at apex, dark brown for nearly the entire length. Conidia very slender, straight, terete, hyaline, 4—6 septate, 20—60 × 1, 5—2.

On dead parts of leaves of *Rhyncospora glomerata*, 2034, Auburn, August 27, 1891, Atkinson.

53. CERCOSPORA ATRAMARGINALIS n. sp. Spots amphigenous, orbicular, 4—6 *mm.*, light brown or dirty grey with black border above. Hyphæ hypophyllous, fasciculate from stroma, short, flexuous or denticulate, continuous, faintly fuliginous, 10—30 × 4—4, 5. Conidia obclavate or cylindrical, 1—10 -septate, guttulate, yellowish, 10—70 × 4—5. Different from *C. Physalidis* E. & E., N. A. F. 2299, and from other forms on *Solanum.*

On leaves of *Solanum nigrum* (?), 1359, Auburn, 1890, Atkinson.

54. CERCOSPORA TROPÆOLI n. sp. Spots amphigenous, very light brown with narrow elevated margin above, suborbicular, 2—4 *mm.* Hyphæ epiphyllous, few in cluster, stout, short, faintly fuliginous, 20—40 × 5, dentate. Conidia hyaline, rather stout at base and quickly tapering into long, slender apical portion, reminding one of *C. flagellaris*, multiseptate, 50—150 × 3, 5—4, 5 at base.

On leaves of cultivated *Tropæolum*, 2110, Auburn, September 7, 1891, Atkinson.

55. CERCOSPORA TESSELATA n. sp. Spots indefinite above, usually narrowly oblong, nearly black below with bluish tinge caused by numerous black tufts and bluish cast of leaf tissue affected. Hyphæ hypophyllous, densely fasciculate, fuliginous, short, 10—12 × 2, 5—3, denticulate, tufts in longitudinal and usually transverse rows, giving a checkered appearance to the group. Conidia slender, hyaline, terete, curved, septate, 50—90 × 2—2, 5.

On languid leaves of *Elusine Ægyptica*, 2306, Auburn, November 6, 1891, Atkinson.

56. CERCOSPORA SERIATA n. sp. Spots amphigenous, cinereous with definite brown border margined by indefinite yellow, irregularly oblong, sometimes confluent. Hyphæ epiphyllous, fasciculate, faint reddish brown, in age darker,

flexuous and toothed, 20—50 × 4, tufts in parallel rows. Conidia hyaline, nearly cylindrical, straight or curved, faintly 2—6 septate, 30—70 × 3—3, 5.

On leaves of *Sporobolus asper*, 2009, Auburn, July 24 and August 7, 1891, Duggar and Newman.

57. CERCOSPORA DAVISII E. & E. Spots brown, subcircular. Hyphæ amphigenous, brown, nearly straight, denticulate near tips, fasciculate, 30—90 × 5. Conidia subhyaline or very faintly yellowish, nearly straight, 5—8 multiseptate, cylindrical or terete, 80—140 × 3, 5—4, 5.

On leaves of *Melilotus alba*, 1268, Uniontown, July 12, 1890, Atkinson.

58. CERCOSPORA ALTHÆINA Sacc. Spots angular, amphigenous, dirty white with narrow black border, 2—3 *mm*. Hyphæ amphigenous, fasciculate, fuscidulous, geniculate or toothed at apex, continuous, 30—50 × 4—5. Conidia hyaline, slender, terete, multiseptate, straight or lightly curved, 30—100 × 3, 5—4, 5.

On leaves of *Althæa rosea*, 1253, Uniontown, July 12, 1890, Atkinson.

Var. MODIOLÆ, n. var. Spots same but little smaller, with narrow raised margin. Hyphæ amphigenous, fasciculate, fuscidulous, continuous, cylindrical, 30—70 × 4, 5. Conidia hyaline, slender and tapering to very narrow apical portion, multiseptate, 50—100 × 3—4.

On *Modiola multifida*, 1253*a*, Auburn, 1890, Atkinson.

59. CERCOSPORA SILPHII E. & E. Spots angular, amphigenous, black or dirty grey with black border, 2—4 *mm*. Hyphæ amphigenous, fasciculate from black base, tufts numerous distributed over the spot, fuliginous with reddish tinge, toothed, longer ones septate, usually 15 25, but up to 70 × 4—5. Conidia obclavate, usually somewhat curved, faintly olive, yellowish tinted, 3—6—septate, 50—100 × 3, 5—5.

On leaves of *Silphium compositum*, 1198, Auburn, June 30, 1890, Atkinson.

60. CERCOSPORA THASPII E. & E. Spots angular, black frequently bordered by indefinite yellow, in age becoming lighter in center, bordered by veinlets frequently, thus giving the appearance of a narrow raised margin, 2—3 *mm.* Hyphæ amphigenous, subfasciculate, 3—8 in a cluster, dark reddish brown, stout, 5—8—septate, guttulate, 70—160 × 5—6, irregularly flexuous, geniculate and sometimes branched. Conidia obclavate, hyaline, stout, closely multiseptate, 60—120 × 5—6 at base.

On leaves of *Angelica hirsuta*, 1540, Auburn, July 22, 1890, Atkinson; 2042, July 23, 1891, Duggar and Newman.

61. CERCOSPORA DEPAZEOIDES (Desm.) Sacc. Spots amphigenous, angular or suborbicular, light brown below, black or greyish above with raised margin. Hyphæ amphigenous, fasciculate, not strongly divergent, distantly septate, dull reddish brown, irregularly flexuous, 100—200 × 4, 5. Conidia faintly tinged with same color, obclavate, septate, guttulate, 50—100 × 4, 5.

On leaves of *Sambucus canadensis*, 1760, Auburn, September 9, 1890, Atkinson.

62. CERCOSPORA SAGITTARIÆ E. & K. Spots amphigenous, angular or suborbicular, light brown, then blackish with indefinite border of a lighter color. Hyphæ epiphyllous, fasciculate, tufts few, fuliginous, simple, denticulate above. Conidia hyaline, straight or curved, obclavate, septate, stout, 40—100 × 4—5. This differs considerably from N. A. F. 1502, but is probably only a variation from that form.

On leaves of *Sagittaria variabilis*, 2039, Auburn, July 24, 1891, Duggar and Newman.

63. CERCOSPORA BOLLEANA (Thüm.) Speg. Spots yellowish and indefinite on upper surface, rusty beneath and

angular, darker in center. Hyphæ hypophyllous, fascicu-late, light olive brown, flexuous or toothed, obscurely sep-tate, 40—70 × 4, 5—5. Conidia lanceolate or tereti-fusoid, 1—5—septate, obtuse, faintly olive yellow, 20—45 × 5—8.

On languid leaves of *Ficus carica*, 1772, Auburn, September 4, 1890, Atkinson.

64. CERCOSPORA CLITORIÆ n. sp. Spots angular, rather large, 3—6 *mm.*, black or nearly black above, brown below. Hyphæ epiphyllous, fuliginous, short, projecting little above the tuberculate stroma, 5 – 10 long. Conidia long, slender, terete, faintly colored, straight or curved, several times septate, 50—70 × 3.

On leaves of *Clitoria mariana*, 2069, Auburn, August 29, 1891, Atkinson.

65. CERCOSPORA EFFUSA (B. & C.) Ell. Hypophyllous, diffuse, giving roseate color to large patches or entirely covering the under surface of the leaf. Hyphæ fasciculate, individuals sometimes creeping and producing numerous branches, geniculate, dentate, reddish, hyaline at tips, 45—100 × 4. Conidia cylindrical, tapering at each end, 1—3 septate, subhyaline, multiguttulate, 25—40 × 4 – 4, 5.

On leaves of *Lobelia amœna*, 2214, Auburn, October 11 and November 3, 1891, Atkinson.

66. CERCOSPORA DOLICHI E. & E. The leaf possesses suborbicular or angular spots mottled with blood-red much as in *C. cruenta*. The hyphæ are not confined to them, but distributed over the green areas of the leaf as well. Hyphæ amphigenous, loosely fasciculate, olive fuliginous, short, subflexuous, subdenticulate and usually somewhat pointed at the apex 20—40 × 4—4, 5, or up to 80 long, then with reddish tinge and plainly septate. Conidia olive, terete, 3 – 15—septate, curved, usually guttulate, 30 – 100 × 4.

On leaves of *Dolichos sinensis*, 1246, Uniontown, July 11, 1890, Atkinson.

67. CERCOSPORA DIOSPYRI Thüm var. FERRUGINOSA n. var. Hyphæ tufted, tufts numerous, collected into olive black orbicular patches on under side of the leaf. Leaves pale green above at the affected places. Hyphæ ferrugineous, irregularly flexuous, closely septate, often branched, rough, jagged, strongly notched and papillate, 50—150 × 4, 5. Conidia obclavate, tapering abruptly toward base, more gradually toward apex, faintly olive yellowish to ferrugineous and dark brown, 1—12 or more septate, septa close and more distinct toward base, in age strongly constricted at septa and nucleolate, 20—80 × 4, 5—5, 5 at base. The conidia are much stouter than in 1273 Myc. Univ. and darker colored even when young. Hyphæ there more slender and continuous as described by Ellis (Jour. Myc., Vol. 1, p. 51). His description is apparently taken from specimens in Thuemen's Myc. Univ., since it agrees with the ones I have examined from that work. Specimens collected by Langlois, 600, in Louisiana, agree with my specimens from Alabama.

On leaves of *Diospyros virginiana*, 2254, Auburn, September 26, 1891, Duggar.

68. CERCOSPORA SORDIDA Sacc. Tufts of Hyphæ forming angular patches limited by the veins, or covering larger portions of the under side of the leaves, dirty grey or nearly black, upper surface yellowish. Hyphæ subfasciculate, divergent, subflexuous, nodulose, denticulate, septate, guttulate, olive reddish brown, 20—70 × 4—4, 5. Conidia faint olive reddish tinge, multiguttulate, multiseptate, terete, curved or flexuous, 20—110 × 3, 5—4, 5.

On leaves of *Tecoma radicans*, 2149, Auburn, September 13, 1801, Atkinson.

69. CERCOSPORA FUSCOVIRENS Sacc. Hypophyllous, spots colored by hyphæ dirty yellowish green, limited by

the veins, indefinite yellowish spots above. Hyphæ fasciculate, faintly olive reddish brown, septate, frequently branched, subflexuous and denticulate toward apex, 30—70 × 4—4, 5. Conidia dilutely yellow, multiseptate and multiguttulate, very long and slender, terete, 70—150—300 × 3, 5—4, obtuse at distal end, abruptly tapering at base. The spores differ greatly in size from Ellis' and Saccardo's descriptions, but the great length of the conidia is probably due to different climatic conditions.

On leaves of *Passiflora incarnata*, 2198, Auburn, October 2, 1891, Duggar.

70. Cercospora Jatrophæ n. sp. Spots indefinite, at first yellowish above and dirty yellow below from hyphæ first developing below, when badly attacked and old hyphæ are amphigenous and then the spots dirty grey with indefinite yellow border. Hyphæ fasciculate from yellowish brown stroma, dilutely yellowish brown, short, subflexuous, 10—20 × 3. Conidia long and slender, hyaline or subhyaline, 5—12—septate, tapering little to distal end, 50—100 × 1, 5—2.

On leaves of *Jatropha stimulosa*, 1171, Auburn, July 2, 1890, Atkinson.

71. Cercospora macroguttata n. sp. Hypophyllous forming small oval or larger narrowly oblong patches, olive brown in color, from the profusion of the development of the fungus. Hyphæ long, flexuous, geniculate, sparingly toothed near apex, multiseptate and multiguttulate with large guttulæ, dark brown in age with olive tinge, growing tips and young ones decidedly olive green tinge, 100—250 × 5—6. Conidia nearly cylindrical, very narrowly tereti-fusoid, dilutely olive green, 3–8–septate, 10–80 × 4, 5—5.

On leaves of *Chrysopsis graminifolia*, 2138, Auburn, July 13, 1891, Atkinson.

72. Cercospora pinnulæcola n. sp. Diffuse, hy-

pophyllous, giving dirty appearance to under surface of the pinnules, which are usually paled above. Hyphæ in loose tufts distributed over affected area, reddish brown, septate, minutely guttulate, irregularly flexuous, geniculate and profusely denticulate, 100—200 × 4, 5. Conidia obclavate, hyaline, multiseptate and multiguttulate, 50—150 × 4—5.

On leaves of *Cassia nictitans*, 2197, Auburn, October 1, 1891, Duggar.

73. CERCOSPORA ERYTHROGENA n. sp. Hypophyllous, spots indefinite, usually reddening the leaf above, giving dirty appearance to large portion of under surface of the leaves. Hyphæ scattered, frequently creeping, often branched, septate, dull reddish brown, flexuous, denticulate, 50—70 × 4, 5. Conidia slender, usually curved, longer ones terete, faintly olive brown, multiseptate and usually guttulate, 30—100 × 3, 5—4.

On leaves of *Rhexia mariana*, 1541, Auburn, July 22, 1890; *Rhexia* sp. 1819, October, 1890; *R. virginica*, 2066, August 29, 1891, Atkinson.

74. CERCOSPORA RIGOSPORA n. sp. Spots indefinite or absent, but parts of leaf affected, usually obscurely yellowish above. Hyphæ hypophyllous, fasciculate, divergent, in sooty patches sometimes very indistinct, or distributed over large areas, fuliginous with olive tinge, subflexuous, denticulate or torulose, longer ones faintly septate and multiguttulate, 50—60 × 3, 5—4. Conidia straight or curved, subcylindrical, abruptly tapering at each end or terete, 3—10—septate, multiguttulate, dilutely olive yellow, 50—70 × 3—4. This is very different from *C. Solani* Thüm as shown in Myc. Univ., 270, and also from *C. diffusa* Ell., specimens of which I have seen, both of those being much stouter and the conidia quite different in texture, easily collapsing, while those of *C. rigospora* are quite firm. Ellis' *diffusa* seems to me on comparison

identical with Thümen's *Solani*. Specimens collected by Langlois, 1322, in Louisiana and marked *C. Solani*, agree quite well with Ellis' *diffusa* and are quite different from my specimens.

On leaves of *Solanum nigrum*(?), 1225, Auburn, July 5, 1890, Atkinson.

75. CERCOSPORA CATENOSPORA n. sp. Diffused in irregular patches or over large surface of under side of leaves, giving dirty green color. Hyphæ fasciculate from stomata of leaf, divergent, 20—30 up to 75 × 5—6, septate, nearly cylindrical, often toothed, bearing conidia laterally as well at the apex, olive yellowish, rarely darker and inclined to faint reddish tinge. Conidia lateral and acrogenous, concatenate or single, cylindrical when concatenate and then abruptly tapering each way to small truncate end, terete when single, more rarely slightly clavate, dilutely olive yellowish, often guttulate, 1—6 septate, 20—100 × 4—5.

On leaves of *Sambucus canadensis*, 2045, Auburn, August 27, 1891, Atkinson. The leaves are severely injured by the fungus, which causes them to curl and fall, so that in many cases the shrubs are entirely denuded of their leaves.

76. CERCOSPORA ERECHTITIS n. sp. On dead parts of the leaf. Hyphæ epiphyllous, fasciculate, reddish brown, geniculate or scarred, in which case hyphæ are cylindrical, frequently guttulate, 50 240 × 4. Conidia hyaline, septate and guttulate, 70—230 × 3—4.

On leaves of *Erechtites hieracifolia*, 2303, Auburn, November 5, 1891, Duggar.

77. CERCOSPORA GOSSYPINA Cooke. Spots light brown or dirty white, irregular, often bordered by a dark or purple color, frequently without spots appearing on large dead or dying areas of the leaf. Hyphæ amphigenous, fasciculate, brown, geniculate or toothed, 70 – 450 × 5—7.

Conidia hyaline, few to multiseptate, terete, 70 400 × 3—4.

On leaves, bracts and cotyledons of *Gossypium herbaceum*.

78. CERCOSPORA LIRIODENDRI Ell. & Hark. I have not collected good specimens of this, but my notes read as follows: "Differs from *C. Liriodendri* (as described) in having conidia 70 long and several times septate."

On leaves of *Liriodendron Tulipifera*, 1951, Auburn, July 11, 1891, Newman.

79. CERCOSPORA CEPHALANTHI E. & K. I have several times collected specimens of this with characteristic spots, but the hyphæ and conidia were so poorly developed it was impossible to take any notes worthy of record.

On leaves of *Cephalanthus occidentalis*.

A NORTH CAROLINA CATALAN OR BLOMARY FORGE.

BY HUNTER L. HARRIS.

This forge is situated on Helton Creek, near its union with North Fork of New River, in Ashe county. It is remarkable as an example of a process for obtaining iron which is now becoming extinct. Briefly, it is the process by which a mass of malleable iron is obtained by heating together in an open hearth a mixture of a pure ore of iron with charcoal, until the carbon monoxide from the charcoal unites with the oxygen of the ore and reduces the ore. There were formerly a number of such forges in that region, but all others have long since disappeared.

This forge was built perhaps fifty years ago by John Ballou; was rebuilt by W. J. Paisley in 1871, and has since been in operation by him, supplying sufficient bar iron for the local demand for wagon tires, horse-shoes, etc.

The plant comprises a two-fire forge, a hammer and an ore crusher, the two latter being operated by separate overshot water-wheels, while the blast for the forge fire is supplied by a third water power arrangement. The forge

Fig. 1 Front view of Forge

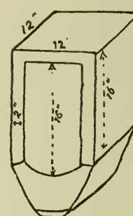

Fig 2.- Hammer.

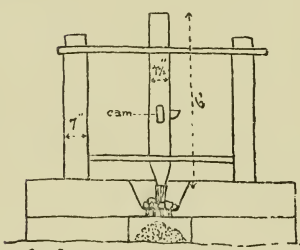

Fig 3.- Ore Crusher

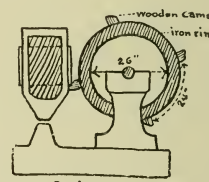

Fig 4 Position of Hammer.

is an open hearth, rudely built of stone fragments. The tuyère communicating with the blast pipe enters this fire space from one side, and the hearth piece consists of a superannuated hammer head built in with the rock fragments.

The blower, said to be similar to the Catalan blower, is a large box, placed 8 or 10 feet below the water supply, and communicating with it by means of a wooden conduit which enters the blower from above.

The blast pipe, also of wood, leads from the upper part of the blower to the tuyère, and near the bottom of the blower at the end is an exit slit for water. When the gate above is opened and the water allowed to enter the blower, air is drawn in with it from openings arranged in the conduit above.

Once in the blower, the water escapes under pressure through the slit, while the air collecting above is forced through the blast pipe and tuyère into the forge hearth.

The hammer is a mass of iron, weighing perhaps 600 pounds, and mounted on the end of a beam, the other end of which is pivoted in an upright post. This post is deeply buried and braced with a heavy beam. The anvil is a similar mass of iron fastened in a wooden block, which is buried in the ground.

The hammer is raised by wooden cams fixed in the periphery of an iron ring mounted as a drum upon an axle. This axle is also the axle of a small overshot wheel, so that when the wheel is set in motion the drum revolves, and the cams engaging the hammer raise it to the height of ten or twelve inches and allow it to fall upon the anvil. The force of the blow is augmented by a spring beam acting downward upon the hammer as it is released. A similar arrangement of cams set in a drum and operated by a separate water-wheel works the ore crusher. This consists of an iron shod beam of about a hundred pounds weight, standing on end in a strong wooden trough, and having a vertical movement, in guys, of about one foot. The trough has an iron grating in the bottom through which the crushed ore (which has been first roasted) falls, and whence it is raked out. The accompanying figures give dimensions and show mode of operation.

Soft ore is washed in an inclined trough by stirring in gently flowing water.

About 100 bushels of charcoal is required to run 250 pounds of ore. Each fire will make three loops a day, each loop yielding from 75 to 80 pounds merchantable bar iron. The iron is wagoned over the surrounding country over a radius of 10 or 15 miles, and is much esteemed for its good working qualities. The whole thing is rude in construction and arrangement and is entirely exposed to the weather. The water supply is abundant and no attempt is made to economize in that particular. Suitable ore is found as friable magnetite in the near neighborhood, but the forge is worked only as the demand may arise.

NOTES ON THE FERTILITY OF PHYSA HETEROSTROPHA SAY.

BY W. L. POTEAT.

In the essay on the "Duration of Life" Weismann remarks that while the length of life of many molluscan species is well known, "any exact knowledge is still wanting concerning such a necessary point as the degree of their fertility."* Binney remarks of the family Limnæidae, to which our snail belongs: "From the fact of my finding young individuals only in the spring and numerous dead full-grown shells during the late autumn and winter, I presume they arrive at maturity in one season."† Of Physa heterostropha in particular he says that it deposits eggs the beginning of May.

In view of these statements I have thought it perhaps worth while to record in this place some observations made by me in the year 1886.

On the 8th of March I collected from a marsh near Wake Forest two specimens of Physa heterostropha Say.‡

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*Heredity, p. 14.

†Land and Fresh-water Shells of N. Amer., p. 23, Vol. VII, Smiths. Misc. Coll.

‡Kindly determined for me later by Dr. Stearnes, of the National Museum at Washington.

On the 16th three thick nidamenta of some forty eggs each were seen loosely attached to the walls of the glass aquarium. A few days later four others had been deposited. Up to June 15th the aquarium was examined at intervals nearly every day. After that date it was not seen again until July 12th, when the water was changed. The next day both the snails were dead, probably as the result of the change of water.

In the period of four months—say March 12th to July 12th—the pair produced 43 nidamenta, which contained, on an estimate certainly not too high, an average of 30 eggs each. So that the number of their offspring for the period mentioned amounted to 1,290. There was no well-marked decline of the reproductive function toward the close of the period, which is perhaps another indication that they came to their death by violence.

From March 31st to June 6th inclusive, the pair were observed in coitu as many as 15 times, at hours ranging from 8:30 A. M. to 6:15 P. M., the coitus lasting sometimes but 20 minutes, sometimes more than an hour. The male function was performed alternately by the two snails. The eggs appear to have been laid only during the night.*

It was important to determine, if possible, the age at which sexual maturity is attained and reproduction begins. Accordingly, on the 12th of July I took out of the aquarium two of the largest of the young snails and put them

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*It may be mentioned, however, in view of the similarity of the habits of Physa and of Limnæus, that I once observed a specimen of the latter depositing a nidamentum on the glass wall of the aquarium at 2:20 P. M. The work was about half done when it caught my eye, and I judge that two minutes were consumed in completing it. The eggs and the protecting jelly emerged at the same time from under the right side of the shell aperture and at right angles to its margin, the snail moving slowly sideways in the opposite direction. When the nidamentum was completed, the snail turned slowly round on the glass, made two or three rather aimless grazing movements of the mouth, and then crawled slowly over the nidamentum in the direction of its longer axis, completely covering it with the foot. That position was maintained but a moment or two; nevertheless the snail remained near by. When I lightly touched the nidamentum and the snail at the same time, the latter shrank a little, but immediately proceeded to cover the threatened nest. During the fifteen minutes that I watched further, the snail remained close to the nest—with the view of protecting it? I thought I detected that the jelly of this one freshly made was somewhat softer than that of an older one near by.

into another aquarium. They were presumably members of the first brood, the eggs of which were deposited near March 13th. Their age, reckoning from the time they were hatched, was about 3½ months; size—length of shell, 5 mm.; length of foot, 6 mm. In two days one of the snails was dead. On the 25th of July another snail of about the same size was introduced from the first aquarium. The next entry in my notes is under date of September 11th, when six nidamenta were observed attached to the fibrous roots of a water plant. They were, however, small, containing only from one to four eggs each, showing that the reproductive fuction at that age was feeble. Some of the eggs were already hatched, and the tiny grandchildren of my first Physas were going about the aquarium in search of food. Allowing, say, fifteen days for the intracapsular development of these snails of the third generation, I estimate that the isolated pair of the second generation attained sexual maturity at five months of age. The same day—September 11th—in the first aquarium I noticed a confirmation of my observation in the second, namely, the pairing of two of the oldest brood.

The maintenance of a species depends on the equilibrium between the forces tending to its destruction and those tending to its preservation. We may embrace the former under the general phrase, adverse external conditions. There are two different ways in which the destructive tendency of these adverse external conditions is opposed. The first is by adaptations of structure and habit. The second is by the production of new individuals to take the place of those that have been overcome. Now, as different animals exhibit varying degrees of ability to adjust themselves to their environment, so also their reproductive power may be small or great. In estimating this reproductive power four factors, as Herbert Spencer points out,*

*Biology, Vol. II, p. 395.

are to be taken account of, namely, (1) the age at which reproduction commences, (2) the frequency with which broods are produced, (3) the number contained in each brood, and (4) the length of time during which the bringing forth of broods continues.

Accordingly, for the special case of Physa heterostropha we have the following results:

1. Age at which reproduction begins, 5 months.
2. Frequency of broods, 1 in about $2\frac{7}{10}$ days.
3. Number in each brood, 30 average.
4. Reproductive period, 4 months, March to July.

Some addition ought to be made to this actually observed period, inasmuch as the snails had certainly already entered upon it at the time of their capture, and, further, instead of closing normally, it seems to have been violently interrupted. Just how much the period of reproduction is to be extended I have no means of determining, unless the fact that the young snails of the first brood were observed reproducing themselves in September warrants an extension of at least two months, making it six months instead of four.*

Assuming, then, that the reproductive season extends from March to September, and assuming, further, somewhat arbitrarily, that the snail lives but two years, we have, on the basis of facts above mentioned, the following estimate of the total number of the offspring of a single pair:

At close of first season	1,900
950 pairs at close of second season	1,805,000
Original pair at close of second season	1,900
Total number offspring in two years	1,808,800

*Packard (Zoology, p. 266) states that the "eggs of P. heterostropha are laid in the early spring, and three or four weeks later from fifty to sixty embryos with well-formed shells may be found in the capsule." The apparent inference that only a single brood is produced must of course be dismissed.

WAKE FOREST COLLEGE, N. C.

OCCURRENCE OF ZIRCONIUM.

BY F. P. VENABLE.

Zirconium occurs principally in the form of silicate in the hard, heavy mineral known as zircon.

That this mineral was known in very early times is highly probable from the number of localities where it may be found and its striking physical properties. Yet it is difficult to assert positively that Theophrastus referred to it under the name lyncurium, or Pliny under the various terms chrysolithos, melichrysos and crateritis. The evidence for the first is based mainly on the fact that it is spoken of as a material from which to cut cameos. Theophrastus says the lyncurium was used for engraved signets, was electric on friction and was often amber-colored.

Whether the ancients distinguished the zircon from other minerals and knew it under any of the above names or not it is certain that intagli of zircon are not at all uncommon among ancient gems.

Agricola and Interpe speak of the jacinth. The first mention of the Ceylonese name Jargon seems to be by Cronstedt in 1758. DeLisle in 1783 writes of the "Diamant Brut ou Jargon de Ceylon." This name Jargon was long used for the colorless and yellowish and smoky zircons of Ceylon in allusion to the fact that while resembling the diamond in lustre they were comparatively worthless. From this comes the name zircon. The colorless or only slightly smoky kinds seem to have often been sold for inferior diamonds.

Brownish, orange and reddish kinds were called distinctively *hyacinths* (topazes and garnets were sometimes called the same).

These zircons occur in crystalline rocks, especially in granular limestone, in chloritic and other schists, in gneiss, syenite, and also in granite and sometimes in iron ore beds. Zircon syenite is a coarse syenitic rock containing crystals of zircon along with oligoclase, aegirine, claeolite and epidote.

Crystals of zircon are common in most auriferous sands and sometimes are found in volcanic rocks.

In Ceylon they are mainly found in the alluvial sands. In the Ural Mountains mainly in the gold regions. In Norway sometimes in syenite, sometimes in the iron mines. Zircons are also found in Transylvania, in Bohemia, in Saxony and in the Tyrol.

The occurrence at Expailly, near Le Puy, in France is well known and of especial interest. Fourcroy says "the hyacinth from Expailly was formerly placed in collections of the Materia Medica to be used in some pharmaceutic compositions."

In Auvergne it is found in volcanic tufa. On Vesuvius it occurs with ryacolite in white and blue octahedrons. In Scotland it is found at Scalpay and in Argyleshire. In Ireland with the auriferous sands. In Greenland, in New Granada, and in the gold regions of Australia, it also occurs.

Coming now to North America we have a long list of localities. In Maine, at Litchfield, Paris, Mt. Mica, Greenwood, Hebron. In Vermont, at Middlebury. In Connecticut, at Norwich and Haddam. In New York, in Essex, Orange, Lewis, St. Lawrence, Warren and other counties. In New Jersey, at Franklin and Trenton. In Pennsylvania, near Reading, in magnetic iron ore; at Easton, in talcose slate. In California, in auriferous gravel in various localities, and in Canada, at several places. Very large crystals weighing as much as fifteen pounds have been found in Renfrew and adjoining counties, but they are so isolated that it would be impossible to obtain a large supply there.

Opaque green zircons have been found an inch long by one-half inch across in St. Lawrence county, N. Y., and five black ones of equal size near Franklin, N. J. One of the New York specimens was over four inches in length and is now in the United States National Museum. An interesting form of zircon is found near the Pike's Peak road, almost due west from the Cheyenne Mountains, following a vein-like mass of white quartz in granite. The crystals are generally deep reddish brown, pink, or pale honey-yellow; and a few crystals of deep emerald green are recorded. The largest observed were about one-third inch, but generally they are not more than one-tenth to one-sixth inch in length and would only cut into minute gems. They are, however, perhaps the most beautiful crystals of zircon known, owing to transparency, brilliancy and perfection. The finest gem stones come from Ceylon, Mudger, and New South Wales (Kunz).

The chief States for yielding zircons are South and North Carolina. At Anderson, S. C., the zircon is found loose in the soil and in large quantities. The containing rock is granulite, or gneiss devoid of mica, and according to Lieber this zircon-granulite corresponds to the zircon-syenite of Norway.

In North Carolina the zircon is abundant in the gold sands of Burke, McDowell, Polk, Rutherford, Caldwell, Mecklenburg, Nash, Warren and other counties in very minute yellowish brown and brownish white, sometimes amethystine, pink and blue crystals. It is mainly found, however, in large greyish brown crystals on the south side of the Blue Ridge near Green River, in Henderson county. Here, in a few weeks in 1869, General Clingman collected one thousand pounds of crystals. The presence of zircons there was known many years prior to this. The occurrence is mainly on what was known as the Freeman and Jones farms, about two miles distant from one another. The deposit runs north-east and south-west, and for many miles zircons can be found, but only at the Freeman and Jones mines in sufficient quantities to work. These are situated on a high ridge. The zircons seem as plentiful on the surface as lower down. The mines have been worked to about the depth of fifteen feet. Before 1860 the zircons were collected from the surface and sold to collectors for about ten dollars a quart. From sixty-five to seventy thousand pounds have since been raised and sold at prices varying from fifteen cents to one dollar per pound. The principal consumers of zircons assure me that there is at present no demand for them, they themselves having a number of tons in stock, all they will need for some years. They are worth about $250 a ton in large lots.

At the Green River mines the dirt is placed in rockers and washed, the zircons and grains of magnetic ore sorting out easily. The latter is separated by means of large magnets. The zircons are from the smallest sand to a quarter of a pound in weight. They are somewhat smaller than the zircons from Anderson, S. C., and easily distinguished from the latter by their form.

When zirconium began to be used a few years ago in incandescent lamps, it was thought to be a comparatively rare mineral. The new application and consequent demand caused a search to be instituted which has shown that in reality it is widely distributed and in places very abundant.

It is to be found in many cases along with titanium, which was to be expected from the chemical relationship existing between the two. Sandberger has observed transparent crystals of zircon in granite of many places; also in gneiss and mica, in diorite and porphyry. Microscopic crystals are widely distributed in the sedimentary rocks, the material of which has been mainly derived from the older rocks; for example, in the variegated sandstones of the Black Forest, in carboniferous limestones and in the sands of the valley of the Maine.

Thürach has shown that microscopic zircon is rarely absent from the archaean and sedimentary rocks. It also occurs in very many eruptive rocks, and it is widely distributed in basalts and dolerites.

Corse reports many localities where it is found in Italy, among them the auriferous sand of Ticino, volcanic sand, and the shore sands of the Tyrrhenian Sea.

The world's main supply, however, if the demand increases, must come from the enormous quantities in the Ural Mountains and in Norway, and from the great and easily workable deposits of Green River, N. C., and Anderson, S. C. Hitherto it can scarcely be said to have been mined in more than one locality, Green River, N. C.

As to other minerals besides the zircon containing zirconium, we have a few, but they are rare and apparently exist in small quantities.

First there are the altered zircons: Auerbachite, Malacone, Cyrtolite, Tachyaphattite, Oerstedite and Bragite.

It is also found in Eudialite, Polymignite, Aeschinite and Fergusonite.

THE MAGNETIC IRON-ORES OF ASHE COUNTY, N. C.*

BY H. B. C. NITZE.

At a time when the mineral resources of the Southern States are attracting such wide-spread interest and attention, I have thought it appropriate to give a short general description of the iron-ore deposits of a territory concern-

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ing which little is as yet known and nothing published, so far as I am aware.

The data used here are due to the preliminary examinations of the North Carolina Geological Survey, on which work I was engaged during the past summer, and my acknowledgments are due to Professor J. A. Holmes, State Geologist, and Messrs. Harris, Ashe and Lewis, of the survey, for their co-operation in the work; also to Messrs. A. S. McCreath and C. B. White for analyses which they kindly furnished. Other analyses were made by Mr. Charles Baskerville, assistant chemist to the survey, and this may be understood where the name of the chemist is not mentioned.

All samples for analysis were dried at 212° F.

The accompanying map has been prepared from the revised sheets of the *United States Geological Survey* by Mr. H. L. Harris, and will be referred to throughout this paper.

Ashe county lies in the extreme north-western part of North Carolina, bordering on Tennessee and Virginia; it is drained principally by the north and south forks of New river and their tributaries, and is therefore on the eastern edge of the great Mississippi drainage-basin. The country is exceedingly rugged and mountainous, having an average elevation of about 2,900 feet above sea-level.

Jefferson, the county-seat, near the center of the county, is forty-five miles nearly due south from the Norfolk & Western Railroad at Marion, Va., and thirty miles northwest from the Richmond & Danville Railroad at Wilkesboro, N. C.

Geologically the ore-deposits described in this paper are situated in the area of the crystalline rocks, consisting chiefly of gneiss, hornblende-schist, and micaceous schists.

These iron-ore deposits, owing to their present inaccessibility, are practically entirely undeveloped. During the summer of 1890 considerable private prospecting was carried on throughout the county, and much of our knowledge concerning the ore-beds is due to this. Many of the openings, however, have caved in to such an extent that but little can be seen at present. More than fifty years ago there were a number of Catalan forges throughout the county, which smelted these ores into a very superior tough iron. One of these now known as Paisley's forge, at the mouth of Helton creek, is still in operation, and made in 1890 from twenty to thirty tons of bar-iron, used locally for wagon-tires, horse-shoes, etc. At present there are no mining operations whatever going on, excepting in a very small superficial way to supply the Helton forge.

The territory to be described in this paper, as including the principal ore-deposits of Ashe county, embraces about 150 square miles. The ores are principally magnetites, chemically suitable for the manufacture of Bessemer pig-iron. Some brown hematites and red specular ores are also found; but, although of excellent quality, their quantity will hardly place them in the category of economic raw materials.

The structure of the magnetic beds is decidedly lenticular, and as such they are distributed over a rather undefinable area, though there is some regularity in the direction of their outcrops, which have a general trend north-east and south-west.

In the following I shall divide them into three main belts, called according to the local nomenclature: The Ballou or River belt, the Red Hill or Poison Branch belt, and the Titaniferous belt.

Starting along the north-eastern extremities of these belts I shall describe the openings along the outcrops in regular order towards the south-west. By reference to the accompanying map their locations and relation to each other can be more easily comprehended than from mere description.

MAP OF THE
PRINCIPAL ORE DEPOSITS
of Ashe County, N. C.

Scale of Miles:
1 2 3 4 5 6

Names of owners or occupants in *italics.*
Ore-outcrops. Prospecting pits etc.

I. THE BALLOU OR RIVER BELT.

This, the most easterly of the three ore-belts, crops out along the north fork of New river, and has been opened at several points on the farm of William H. Brown.

Opening No. 1 on the west bank of the river at the falls, about one mile north of Crumpler P. O., is a large cut, exposing probably 30 feet of ore-material, composed of hornblende, gneiss, and epidote, which is split up at three points by lenticular masses of magnetite. From the condition of the exposure it was not possible to determine the true thickness of the ore.

An analysis of an average sample from here shows:

	Per Cent.
Silica	27.59
Metallic iron	53.99
Sulphur	0.055
Phosphorus	0.063

The ore crosses the river north-easterly from here to the property of John C. Plummer, but no openings have been made.

Opening No. 2 is located about half a mile west of the river, near Mr. Brown's house.

This cut was also partially caved in and filled with water, so that a clear inspection was not practicable. The exposed material shows:

1. About 4 feet of soft decomposed schistose gangue, carrying finely disseminated grains of magnetite; above this,

2. About 5 feet of decomposed mica-schist and quartz; and above these, towards the face of the cut,

3. About 12 feet of mixed material containing strips of harder, richer ore, 2 feet and more in thickness.

Of the soft ore it has been found by washing that fully 50 per cent. is magnetite, an analysis of which by Mr. A. S. McCreath shows:

	Per Cent.
Silica	2.40
Metallic iron	67.35
Phosphorus	0.028

The unwashed material shows 43.50 per cent. of metallic iron.

An analysis by Mr. Baskerville of an average sample across the entire bed shows:

	Per Cent.
Silica	5.73
Metallic iron	60.48
Sulphur	0.003
Phosphorus	trace.

South-westerly the ore crosses the river about one mile from here, and makes its appearance in a very prominent outcrop over the property of N. B. Ballou, known as the "Home Place," on the east side of the river, between the mouths of Helton and Old Field creeks. It recrosses the river, which makes a large bend at this point, about half a mile from here, near Uriah Ballou's house, and near this second point of crossing some work was done a number of years ago for one of the old forges, showing the approximate thickness of the bed to be 12 feet. The dip is about 37° S. E., and the strike N. 45° E.

The ore is a hard, compact, fine-grained magnetite disseminated in a gangue of hornblende, epidote, and quartz. Higher up on the hill some small, superficial openings expose several smaller ledges of richer ore, comparatively free from gangue. But it is believed that the following analyses will represent the quality of the ore as it must be mined:

	I.	II.	III.
Silica	20.79	---	17.88
Metallic iron	45.50	49.06	50.68
Sulphur	0.002	---	trace.
Phosphorus	0.024	0.018	trace.

Analysis I. is by McCreath.
II. is from U. S. 10th Census Report.
III. is by Baskerville.

Towards the south-west the ore crosses and recrosses the north fork and becomes thinner-bedded. It crops out about one mile from Ballou's on the farm of Dr. Gentry in a high bluff along the east bank of the river, showing a maximum thickness of 2 feet, and apparently pinching out to considerably less than that. An analysis of an average sample taken here shows:

	Per Cent.
Silica	16.68
Metallic iron	47.22
Sulphur	0.063
Phosphorus	trace.

There is a second line of outcrop, about half a mile south-east of the above main outcrop, which has been traced from Brown's on the north fork, about half a mile above the river opening at the falls, in a south-westerly direction, crossing the river at Shubal Lunceford's, almost one mile due north from Crumpler P. O., and continuing through Ballou's and Gentry's lands. This has been opened on Lunceford's place, about a quarter of a mile north of the river, exposing a bed of soft, granular ore, disseminated in mica-schist, which measures 13 feet in thickness, and dips 52° S. E. An analysis of a sample taken across the bed shows:

	Per Cent.
Silica	38.73
Metallic iron	41.36

II. THE RED HILL OR POISON BRANCH BELT.

This belt extends from the north-eastern corner of the county in a general south-westerly direction, its several lines of outcrop crossing over Grassy creek, Helton knob, Red Hill, Helton creek, McClure's knob, Old Field, Silas, Piney and Horse creeks, a distance of some ten miles, as far as traced. It lies from two to three miles north-west of the river belt, and approximately parallel to it.

It has been opened at numerous points along its outcrop, beginning at its north-eastern end on the land of Lee Pugh on Ben's branch, about ⅓ mile north of New river, where a bed at least several feet in width is exposed, but is not fully uncovered. The ore is a friable magnetite of schistose structure. The dip is from 35° to 40° S. E.

An analysis of an average sample shows:

	Per Cent.
Silica	22.74
Metallic iron	45.44
Sulphur	0.049
Phosphorus	0.022

About 400 yards S. 40° W. from here the bed has been exposed on the land of John L. Pugh, on the summit of a high ridge, by a cut 105 feet long, the south-eastern end of which traverses a bed of soft mixed ore and gangue, reported to be 40 feet thick, while the north-western end cuts through about 30 feet of similar material, though harder. Between the two is a decomposed feldspathic mass, probably a local horse.

The cut was partially caved in, so that exact measurements could not be taken. The ore is a coarse-granular, friable, manganiferous magnetite, and the gangue is hornblende, epidote, quartz, and feldspar. Several analyses show the ore to contain:

	I. Per Cent.	II. Per Cent.
Silica	21.11	---
Metallic iron	43.17	44.13
Metallic manganese	4.62	1.42
Sulphur	0.048	0.126
Phosphorus	0.006	0.008

I. by Baskerville.

II. by C. B. White.

The bed is again opened on the properties of W. W. Smith and Noah Dancy, lying successively to the south-west of Pugh's, but the exposures are incomplete and offer no definite data. Several analyses by Mr. C. B. White show the quality of these ores to be:

	Iron. Per Cent.	Phosphorus. Per Cent.
"Smith" ore	55.76	0.040
"Dancy" ore (surface sample)	63.49	0.176

The next notable exposure occurs on the Black property, on the north-eastern slope of Helton knob, on the waters of Grassy creek, where several old "forge" banks are located, whence the Paisley forge still draws its limited supply. The old openings are now completely fallen in, and nothing can be seen excepting the fact that there seem to be two beds about 30 feet apart, the upper one of which is reported to be 2 feet thick. The ore is soft and decomposed, in a friable, schistose gangue; and it is on account of this softness that it was particularly prized by the forges.

Higher up on the same hill similar float-ore is repeatedly met with, scattered over the surface, and it seems to cover a large area.

About ¼ mile slightly south of west from these old "forge"-openings is a very prominent outcrop of hornblendic gneiss, at least 40 feet high, containing lenticular masses of hard, compact magnetite, showing a thickness of 3 feet at one point; and about 200 yards S. 60° W. from here, on another ridge, some heavy and exceptionally pure masses of float-ore were observed, indicating the existence of another parallel series of ore-beds. Unfortunately none of the analyses of these ores were completed in time for this paper.

The "soft" ore, as used in the Paisley forge, is first washed in an inclined wooden trough by a gently-flowing stream of water; and an analysis by myself of this washed product shows:

	Per Cent.
Silica	11.075
Metallic iron	58.930
Sulphur	0.068
Phosphorus	0.033

In explanation of the formation of these deposits of "soft" ore, such as occur on the Black, Red Hill, and other properties to be described hereafter, it may be said here that all indications go to show that they are undoubtedly due to the breaking down of the original outcrops of magnetite and magnetic rocks, subsequent to the erosion of the more readily decomposable surrounding strata, and their consequent spreading over large superficial areas of comparatively limited depths. At the same time their replacement may have been so regulated by nature that they still exist in workable deposits, and the original beds might be expected either directly beneath or in close proximity to them; but this can only be definitely settled by further exploitation.

As shown in several places much of this "soft" ore can be concentrated to a comparatively high-grade material by simple washing alone, and there is no reason why, by means of magnetic concentration, a highly desirable product should not be obtained. Even the hard ores, high in silica, are susceptible of concentration, after previous crushing by this process; and at the well-known Cranberry mines in Mitchell county experiments are being very successfully carried on in this direction.

By means of the dipping-needle the ore was traced across the summit of Helton knob, which rises to an altitude of 3,410 feet above sea-level. On the south-western slope of Helton knob several small openings on the property of Joseph Jones expose the ore-bed, but not sufficiently to furnish much definite information. On the western foot-hills of Helton knob, on Robert's branch, a tributary of Helton creek, an opening on David Blevins' land exposes an ore-bed, showing three streaks of ore, respectively 7½, 4½, and 2 feet in thickness, separated by a gneissoid material, probably a local horse. The dip is 40° S. E. The ore is a compact magnetite in a gangue of hornblende and epidote.

An analysis of an average sample shows:

	Per Cent.
Silica	29.901
Metallic iron	36.350
Sulphur	0.038
Phosphorus	0.022

Between here and Helton creek, a distance of about one-quarter of a mile across, is the Red Hill property, over which a number of openings have uncovered a rather intricate and distributed ore-formation.

The main opening, No. 1, is a trench through the comb of the hill, over 200 feet in length, through a decomposed schistose and argillaceous material, carrying almost throughout its entire extent mixed masses of soft ore, hard ore, and crystalline sandy ore, distributed irregularly through the gangue; it is evidently one of the broken-down re-deposits, before alluded to.

At the eastern end of the cut some pyrites was mixed with the material. An analysis of an average sample shows:

	Per Cent.
Silica	19.83
Metallic iron	51.55
Sulphur	0.137
Phosphorus	0.042

Opening No. 2, about 30 yards W. S. W. from the above, exposes a solid bed of magnetite in epidote and quartz, over five feet thick, dipping south-east. No pyrites was observed here. An analysis shows:

	Per Cent.
Silica	31.26
Metallic iron	36.21
Sulphur	0.07
Phosphorus	trace.

Opening No. 3, on the north-west side of the hill, shows a broken bed of ore in a gangue of hornblende and epidote, with concentrations of pyrites at several points. The entire thickness of the bed must be over 10 feet. An analysis shows:

	Per Cent.
Silica	32.59
Metallic iron	36.41
Sulphur	0.20
Phosphorus	trace.

On the immediate northern bank of Helton creek a small opening exposes a broken bed of compact magnetite, irregularly distributed through a gangue of hornblende and gneiss, split by a lens of pyritiferous ore about 5 feet thick. An analysis of a sample taken across the bed shows:

	Per Cent.
Silica	41.13
Metallic iron	23.39
Sulphur	1.67
Phosphorus	0.109

The conclusion is that there are streaks of pyritiferous ore throughout this part of the bed, which increase in sulphur with depth.

On the south side of Helton creek the ore crosses over McClure's knob, where a number of openings expose a series of three parallel beds, none of which show over 3 feet in thickness so far as developed. A number of analyses of samples taken from some of these openings show:

	I.	II.	III.	IV.
Silica	23.23	22.78	28.78	16.50
Metallic iron	44.87	43.03	42.39	45.87
Sulphur	0.036	0.02	0.03	0.025
Phosphorus	0.053	0.14	0.03	0.904

To the south-west the ore crosses Old Field creek, and has been opened again at the Poison branch bank, on the divide between the waters of Old Field and Silas creeks, where considerable work was at one time done for the old forges.

The main opening exposes a bed of magnetite consisting of two parts, the upper one being visible only in the upper end of the cut just below the surface-soil, where it measures about 4½ inches in thickness of friable crystalline magnetite, comparatively clean, below which is a bed of argillaceous schist and clay, of a deep vermilion color, containing fine shot ore disseminated through it, probably forming a more decomposable part of the same bed. Unfortunately the cut had not been extended far enough in this direction to determine its true thickness. The lower bed is seen some 30 feet below here, at the bottom of the cut, near its mouth. It is partially filled in here, but I have from good authority that its thickness is 6 feet, about 3 feet of which was visible at the time of my visit. It is a hard ore, and the gangue is entirely hornblendic, while in the upper bed it is micaceous. The dip is about 50° S. E., and the strike N. 40° E. Several analyses of the lower bed show:

	I.	II.	III.
Silica	12.31	----	----
Metallic iron	56.05	56.00	50.77
Sulphur	----	0.05	0.076
Phosphorus	0.071	0.013	0.016
Titanic acid	----	trace.	----

I. by McCreath.
II. by C. B. White.
III. from U. S. 10th Census Report.

Not over 100 feet south-west from here another old opening exposes the same bed 25 feet lower.

In a south-westerly direction the ore has been traced to Silas Creek, but no openings of importance have been made.

Some 2 miles S. W. from Poison branch bank a bed of soft schistose ore has been opened on the land of John Parsons, on Little Grapevine creek. The opening is a very narrow and shallow one. It shows not less than 3 feet of ore, but the bed is not fully exposed.

Less than half a mile north-west from here, on Douglas Blevin's land, an opening on the top of a high ridge exposes another ore-bed at least 8 feet thick. The ore is extremely hard, in a gangue of hornblende gneiss. The dip is 45° S. E.

About half a mile south-west from here, on Piney creek, 1½ miles above its mouth, at Ballou's mill, a large bed of manganiferous magnetite has been uncovered. The ore is very coarse-granular in a matrix of brownish-black manganese oxide. It is exceptionally pure and practically free from gangue throughout its entire extent. The upper part of the bed shows 6½ feet of solid hard ore, beneath which is about 1 foot of soft manganiferous ore. The bed is probably even thicker than this, as its full extent has not been uncovered. Several analyses show it to contain:

	I.	II.	III.	IV.
Silica	3.20	0.800	10.64	0.614
Metallic iron	65.40	65.65	39.35	65.090
Metallic manganese	2.58	3.83	9.63	3.98
Sulphur	----	----	----	0.0069
Phosphorus	0.011	0.004	0.022	0.019

I. by C. B. White.
II. "Hard" ore by McCreath.
III. "Soft" ore by McCreath.
IV. "Hard" ore by C. Baskerville.

Crossing Piney creek, the same bed has been uncovered about half a mile S. W. from here, on the land of Robert Francis, where a slope, 20 feet deep, exposes 10 feet of soft manganiferous ore on the outcrop, pinching out to considerably less than this at the face of the slope. Throughout this soft material are scattered grains of hard magnetite. There is evidently a roll or fold in the bed at this point, the dip being abnormally 20° north of east, and the strike N. 34° W. The foot-wall is a decomposed feldspathic material. The ore carries an excessive amount of hygroscopic moisture. Analyses of the natural and dried ore, by Mr. A. S. McCreath, show:

	Natural Ore.	Dried at 212° F.
Silica	3.496	6.090
Metallic iron	27.236	47.450
Metallic manganese	5.224	9.102
Phosphorus	0.058	0.102
Moisture at 212° F.	42.600	-----

About half a mile due west from here, a bed of very hard, compact, crystalline magnetite has been opened at two points, differing 100 feet in elevation, on Jacob Stewart's land near the summit of Turkey knob. The gangue is hornblende and quartz. The openings were filled in, but the ore was reported to be 5 feet thick.

An analysis by Mr. White shows:

	Per Cent.
Metallic iron	63.501
Phosphorus	0.006
Titanic acid	trace.

The ore has been traced half a mile north-east from here to the William Hamm place.

About three-quarters of a mile south-west from the Francis opening, on the waters of Old Field creek, a tributary of Horse creek, a number of openings on the southwestern spur of Turkey knob, on the land of Joseph Graybeal, have exposed a bed of magnetic ore, which was worked a number of years ago for some of the old forges. One of these old openings shows a great deal of soft, mixed shot-ore disseminated in decomposed schist, with a streak of manganiferous earth in the front part of the opening. The main opening is a cut about 50 feet long, exposing two beds of ore, respectively 4 and 18 feet thick, separated by a horse of clay. The 4 feet of ore in the front part of the cut showed some very compact, solid magnetite. The ore in the upper part of the cut was mixed with hornblende gangue. Between these two openings some manganiferous float-ore was observed, resembling very much that at the Piney creek and Francis openings.

Several analyses of the Graybeal ore show:

	I.	II.	III.
Silica	6.85	----	----
Metallic iron	63.55	67.18	64.04
Sulphur	trace.	----	----
Phosphorus	trace.	0.010	0.009

I. by Baskerville.

II. by White.

III. from U. S. 10th Census Report.

On Horse creek, about one mile above its mouth, a bed of magnetite, precisely similar to that at Piney creek, has been opened. It is a coarse-granular magnetite disseminated in a manganiferous matrix, which decomposes on long exposure into a soft, rich shot-ore. The opening is in the shape of an under-cut in the side of a hill, into which it extends perhaps 20 feet as a slope, the lower part of which was filled with water, preventing a close examination. As far as exposed, the thickness of the ore is at least 6 feet, the lower 2 feet being the harder. Analyses show:

	I.	II.
Silica	4.12	1.96
Metallic iron	64.58	62.48
Metallic manganese	2.21	3.66
Phosphorus	0.011	0.019

I. by White.

II. by Baskerville.

Over one mile south-west from here the ore-body rises over 500 feet above the level of Horse creek, on Hampton knob, over which it has been traced for considerable distance by the dipping-needle. But none of the openings give any idea of the size of the bed. Several analyses from the locality show:

	I.	II.
Silica	9.66	---
Metallic iron	61.58	65.63
Sulphur	0.06	----
Phosphorus	trace.	0.029

I. by Baskerville.
II. by White.

III. THE TITANIFEROUS BELT.

Starting at the northern edge of the county, on the Virginia line, on the waters of Little Helton creek, this, the most north-westerly ore-belt of importance in Ashe county, has been traced in a south-westerly direction, crossing Helton creek near Sturgill P. O., a distance of some 2½ miles. It lies, approximately, 3 miles north-west of the Red Hill belt, and parallel to it.

On the property of William Young, 150 yards west of the Jefferson-Marion road, and about ¼ line south of Virginia State-line, a very heavy outcrop of magnetite extends east and west along the crest of a ridge, with a width of at least 25 feet. There are no openings here, but all indications point to the existence of a large deposit. The ore is a coarse-granular, compact magnetite, practically free from gangue. It is titaniferous, and has a bright silvery luster. An analysis by McCreath shows it to contain:

	Per Cent.
Silica	4.35
Metallic iron	52.85
Phosphorus	0.013
Titanic acid	8.800

This outcrop is traced for over 150 yards in a westerly direction across Shippy branch, where it is opened on the McCarter place, showing a bed from 9 to 12 feet thick, dipping almost vertically. The local magnetic variation was 11° W.

An analysis by McCreath shows:

	Per Cent.
Silica	5.37
Metallic iron	51.75
Phosphorus	0.018
Titanic acid	9.17

The bed is again uncovered, about 350 yards west from here, in front of Mr. McCarter's house, by a shallow cut showing about three feet of ore; but the bed is not fully exposed.

About half a mile farther south-west, an opening on the Bauguess place shows 5 feet of ore, having a reddish streak, an analysis of which by myself shows 4.80 per cent. of titanic acid.

The next notable opening, about one mile south-west from here, on Wallen's creek, a tributary of Helton creek, on the Pennington place, exposes a bed 8 feet thick, an analysis of which by McCreath shows:

	Per Cent.
Silica	5.07
Metallic iron	52.45
Phosphorus	0.022
Titanic acid	9 11

About half a mile north of Sturgill P. O., on the waters of Helton creek, on the Kirby place, a broken bed of hard, fine-gained magnetite of steel-gray color has been uncovered. Its extent could not be determined from the condition of the opening, but its thickness appears to be not less that 15 feet.

I am indebted to Mr. A. S. McCreath for the information that these titaniferous ores carry a small amount of chromium, and an average analysis of a number of samples shows 0.480 per cent. of chromium.

This concludes a description of the location and some of the economic features of the principal ore-deposits of Ashe county; and it is hoped that this region may become an important source of ore-supply in the near future.

In general, the quality of these ores is good; low in sulphur, and below the Bessemer limit in phosphorus.

The mined material will, in many cases, be high in silica, but there is no reason why, by means of magnetic concentration, a high grade product should not be obtained.

The titaniferous belt is by far the most persistent, and shows a large quantity of ore, but the percentage of titanic acid condemns this material for blast-furnace use, at least in competion with iron-ores less difficult to smelt to pig-iron.

There is little doubt that there are valuable, workable beds of ore throughout the other two belts, such as at Ballou's, Piney creek, Graybeal's, Horse creek, etc., but it will require much more extensive exploitation to define their true extent.

Other beds of ore have been uncovered throughout the county, but they are rather out of the range of what is considered to be the principal ore-region.

Such are, for instance, a bed of magnetite 9 feet thick, on the Ben Greer place, on the waters of Little Horse creek; and a belt of brown hematite along the north-western slopes of Phœnix and Three Top mountains, which is supposed to be a secondary formation, and of little importance as compared with the magnetic ores.

Nearly all of these ore-deposits, being situated on tributaries of the north fork of New river, would be accessible to a railroad built up that stream, which is a very feasible project.

NOTE BY THE SECRETARY.—Comments or criticisms upon all papers, whether private corrections of typographical or other errors, or communications for publication as "Discussion," or independent papers on the same or a related subject, are earnestly invited.

NOTES ON THE DEVELOPMENT OF SOME SPONGES.*

BY HENRY V. WILSON.

The following notes deal with the gemmule development of *Esperella fibrexilis* (n. sp.) and *Tedania Brucei* (n. sp.), to which are added a few observations on the egg development of *Tedanione fœtida* (n. g.) and *Hircinia acuta*. *Esperella fibrex.* is a small silicious sponge abundant near Wood's Holl, Mass. The others are Bahama forms found at Green Turtle Cay, the two silicious sponges, Tedania and Tedanione, being closely related.

During the summer, Esperella and Tedania contain great numbers of embryos in all stages of development, and if the sponges are kept in aquaria for a few hours, some of the embryos will pass out through the oscula. The embryos thus set free are solid oval bodies covered with cilia, and are quite like the egg larvæ of many silicious sponges. They swim about for a day or so and then attach themselves to the wall of the dish, flatten out and undergo a metamorphosis. When the embryos inside the mother are examined, they are found not to be egg embryos, but true gemmules; *i. e.*, internal buds.

I will first describe the development of Esperella. The mesoderm of Esperella contains cells, which differ greatly in size and general appearance, though they shade one into the other. Some of the cells are much larger than the rest and have plump bodies, which stain well. Such cells congregate together and form irregular groups, in which the cells are rather closely packed. The group of cells rounds itself off, the outer cells becoming flattened

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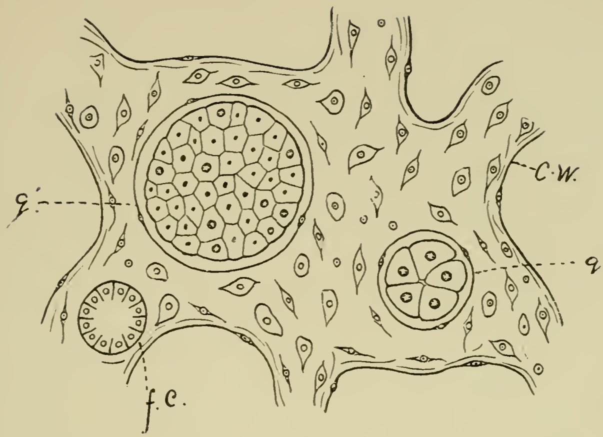

FIG. 1. Portion of Esperella mesoderm, showing two gemmules, *g* and *g'*, each surrounded by follicle of flattened cells. *g* is a very young gemmule; *g'*, considerably older; *c. w.*= canal wall; *f. c.*= flagellated chamber.

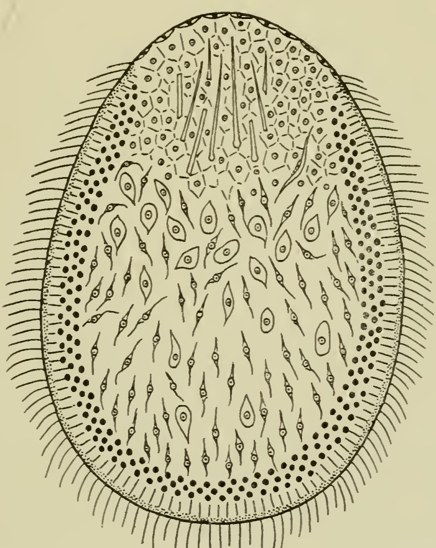

FIG. 3. Longitudinal section through the swimming larva of Esperella. The nuclei of the columnar ectoderm cells form a conspicuous zone. In the outer ends of these cells is orange pigment. The inner mass of cells (parenchyme), in the region of non-ciliated pole, differs from the parenchyme in the rest of the body.

FIGURES ILLUSTRATING "NOTES ON DEVELOPMENT OF SPONGES."

and forming a follicle. The gemmule, as thus formed, is at first quite small, often showing not more than five cells in section, though a considerably larger gemmule may be directly formed from a group of cells. The cells of the gemmule, once the follicle is formed, are very closely packed.

The increase in size of the gemmule takes place by means of cell growth and division, and by the fusion of neighboring small gemmules. The latter process throws into shade the seemingly important question, Does a gemmule ever start as a single cell? In regard to the actual occurrence of such an origin for gemmules, I may say that, after looking over a great number of preparations, my conclusion is, that perhaps a little group of mesoderm (gemmule) cells is so derived in very rare instances, but the case occurs so seldom as not to be worth consideration.

The gemmule continues to increase in size, without any striking change in its structure, until it is nearly as large as the swimming larva. In this condition it may be spoken of as the ripe gemmule. The ripe gemmule is spheroidal and is made up of cells so closely packed and so filled with fine yoke granules that the cell boundaries are indistinct. The nuclei of the cells are very small. During the growth of the gemmule the surrounding tissue becomes largely incorporated in the follicle; and whereas the gemmule in its early stages lay in the mesoderm of the sponge, in its ripe condition it lies in one of the larger canals, suspended by strands of tissue which now bind the follicle to the canal wall. The ripe gemmule next undergoes a process which presents a superficial analogy to segmentation. The solid gemmule splits up into irregular masses of cells. These continue to split up into smaller and smaller masses, the gemmule meanwhile increasing in size, owing to the absorption of fluid, so that the several masses of cells are distinctly separated from one another. The splitting up continues until the solid gemmule has been plainly resolved into its constituent cells. The outer cells of the gemmule, very early in this process of "segmentation," arrange themselves so as to form a continuous layer of flat cells round the periphery. This layer, for convenience's sake, may be spoken of as the ectoderm. Inside the ectoderm at the close of "segmentation" is found a mass of amœboid cells connected together by their processes and separated by fluid. The flat ectoderm cells next become long slender columnar cells, having pigment in their outer ends and bearing cilia. The metamorphosis of the ectoderm cells does not, however, take place over one pole. Over this pole the ectoderm cells remain flat and without cilia. Further, the inner mass of cells at this pole become steadily denser, until this region of the embryo is occupied by a mass of irregularly polygonal cells closely appressed. In the mass of polygonal cells a bundle of long spicules lying in the direction of the main axis of the embryo is developed. In the remainder of the inner contents of the embryo, the cells are less closely packed and are of various shapes. The unciliated pole is made the more conspicuous because of the pigment (orange) which covers the rest of the embryo. In this condition, the embryo breaks through its follicular wall, and passes out of the parent through one of the oscula.

The first step in the metamorphosis of the larva consists in the flattening of its ectoderm. The flattening begins before the sponge attaches itself, and *gradually travels from the non-ciliated or spicular pole backwards.* While there is still a considerable remnant of the columnar ectoderm, the larva attaches itself by the spicular pole, but obliquely, so that it lies somewhat on its side. The rest of the ectoderm then becomes flattened, and the lava is transformed into a thin, flat mass, circular in outline. The bundle of spicules, formerly at the non-ciliated pole, become distributed all over the body of the little sponge. The attached larva, at first circular in outline, speedily grows irregular in shape, and becomes surrounded by a thin ectodermal membrane. The subdermal cavities and canals appear as lacunæ in the substance of the larva, the surrounding cells becoming flattened to form the epithelioid wall. The various canals and cavities, originally independent, open one into the other, and to the exterior, by simple perforation of the intermediate tissue. The oscula and pores are at first indistinguishable, and are scattered over the surface of the sponge, with no attempt at arrangement. Even in the adult I can see no morphological distinction between the pores and oscula. The difference in size is the only difference, and that loses its significance because of the occurrence of apertures, which hold several intermediate positions in this respect between pores and oscula.

The flagellated chambers arise as independent structures, which subsequently acquire connection with the canal system.

There are in the larva, when it first attaches, a large number of mesoderm cells, distinguishable from the rest by their size and bulky shape. Such cells I may call formative cells. They diminish greatly in number, and grow smaller in size during the metamorphosis. The formative cells contain as a rule several nuclei, and are destined for the most part to split up into much smaller cells. The particular way in which the flagellated chambers are formed in any larva depends on the behavior of the formative cells. (All the cells of the larva, I may add, are connected together by fine processes). In some larvæ the formative cells arrange themselves round a central cavity (intercellular space) so as to form a hollow sphere. Numbers of such spheres, consisting of comparatively large cells, are found in some larvæ. Division of the cells then ensues, and the hollow sphere gradually assumes the nature of a flagellated chamber. In some larvæ, on the other hand, all the formative cells may break up into fine cells before the marking out of any flagellated chambers. The mesenchyme of such larvæ consists of a solid mass of fine cells, with here and there a formative cell. The flagellated chambers of such a larva must be formed directly from a group of fine cells, probably by some rearrangement of the cells round a central cavity. In other larvæ, both processes go on at the same time. Some of the formative cells arrange themselves in hollow spheres and form chambers directly, others break up into solid masses of small cells, which subsequently acquire a cavity. That a single formative cell itself ever forms a chamber, I do not believe.

In whichever way the flagellated chamber is formed, it at first has no connection with the canals. It, like any particular canal, is, in its origin, a lacuna, its cavity being an intercellular space.

In deciding phylogenetic questions, perhaps not much weight should be attached to a development like this; but whatever weight it has, is in favor of Metschnikoff's theory of the solid ancestry of sponges. The solid swimming larva itself, and the details of the metamorphosis (the origin of the flagellated chambers, excurrent and incurrent canals, and subdermal spaces, as independent lacunæ in a matrix of amœboid cells) are all understood on this theory. Conversely, if we hold to the view which regards the calcareous sponges (Ascons) as the primitive type, the development of Esperella may, of course, be regarded as an extreme case of coenogeny.

The development of Esperella, it seems to me, has perhaps a bearing on problems out of the range of pure morphology. Without discussing the matter in detail, I may point out the striking resemblance between this asexual development and the egg development of many silicious sponges. As in the egg embryo, there are formed in the gemmule embryo two germ layers. In the two embryos the layers are alike in many details of structure. The egg larvæ, again, are characterized by the absence over one pole of the columnar ectoderm (Isodyctia and Desmacidon, Barrois (1); Reniera, Marshall (2); Chalinula, Keller (3); Esperia, Schmidt (4), etc.). The account according to which the endoderm protrudes at this pole, is probably not correct, but it is likely that the ectoderm is only greatly flattened over this region. It is this characteristic more than any other, which I should pick out as a point of exact resemblance between the sexual and asexual larvæ. Barrois has described the egg development of two forms, in one of which (Isodyctia) the non-ciliated pole of the planula is never covered with columnar cells. This is paralleled by the Esperella larva. In another form (Desmacidon), the larva has at first a complete covering of columnar ectoderm (and cilia), which then disappears over one pole (and much later over the whole surface). This case is more or less similar to the gemmule development of Tedania; in this form, the embryo has at one time a complete covering of columnar cells (unciliated however), which *flatten out* over one pole, while over the rest of the body they acquire cilia. In the metamorphosis, also, the gemmule development resembles the egg development, in that the ectoderm of the larva is flattened to form the ectoderm of the adult. As regards the formation of the chambers, canals, etc., the egg larvæ differ too much among themselves to permit any such comparison as I am carrying out

Such a resemblance between the sexual and asexual larvæ as I have indicated, can, I think, only be explained on the supposition of some essential likeness between the mesoderm cells, which make up the gemmule, and ova.

If for convenience's sake we adopt the point of view of Weismann, and regard the egg cell as characterized by the possession of a "germ plasm," the gemmule cells too (unless the resemblances between the gemmule and egg embryo are accidental) have some claim to the possession of this plasm. By making a little further use of Weismann's theory, the nature of the gemmule cell (*i. e.*, a mesoderm cell, which, together with others, forms a gemmule) may perhaps be stated with some precision. Of the two polar bodies found in non-parthenogenetic eggs, Weismann believes that the first carries off ovogenetic plasm, the second carries off one-half the germ plasm. In the case of the sponge gemmule, a mesoderm cell does not itself become differentiated into an ovum, but the necessary amount of nutriment for the embryo is got by the association of numerous such cells. Hence there is in the gemmule cell no special histogenetic (ovogenetic) plasm, and consequently no first polar body. There is, of course, no fertilization, therefore no second polar body. The gemmule cell, according to this view, must be regarded as a true germ cell, in which all the germ plasm remains undifferentiated, viz., in which none of it is transformed into ovogenetic plasm. Further, the gemmule cell pursues the parthenogenetic course of development—it keeps all its germ plasm.

Gemmules apparently develop anywhere in the sponge mesenchyme. It must, therefore, be assumed that *any* mesenchyme cell may become a gemmule cell, and consequently that it contains germ plasm. The same conclusion is reached by the study of the egg development, for it seems that any mesenchyme cell may develop into an egg.

The gemmule development in Tedania pursues much the same course as in Esperella. The early stages in the formation of the gemmule, owing to the extremely small size of the cells, cannot be followed with the same accuracy as in Esperella, but the process can be seen to be essentially the same. The "segmentation," or gradual dissolution of the gemmule into its constituent cells, takes place in the same way. The swimming larva is, except in a few details, like the larva of Esperella, and the metamorphosis takes place on the same lines.

In the egg development of Tedanione, there is a total segmentation, resulting in the formation of a solid morula. The larva, when set free, is a solid oval body, completely covered with a layer of columnar ciliated cells. The metamorphosis was not observed. The segmentation of Hircinia is likewise a total segmentation, resulting in the formation of a solid morula. The development of the ovarian egg in these two forms is essentially alike. The follicle during the growth of the egg is surrounded by a large number of comparatively densely packed mesenchyme cells, the duty of which is presumably to bring nourishment to the growing egg (compare Fiedler's account for Spongilla). The nucleus of the very young egg contains a single large nucleolus more or less centrally placed. While the egg is comparatively small, before it has reached more than one-half its ultimate size, two small spherical masses of densely staining chromatin are found adhering to opposite sides of the inner face of the nuclear wall. As a rule, in eggs which have reached the full size, only one or neither of these chromatine balls is present.

Occasionally, however, an egg is found of the full size and still with both of the chromatin balls. One of the masses is probably lost (thrown out?) about the time when the increase in size is completed. The remaining mass is thrown out of the nucleus, and may sometimes be observed lying in the egg yoke near the nucleus. The nucleus of the ripe egg thus left without chromatin mass, is a poorly defined body in which neither nuclear membrane nor chromatin is visible. The maturation of the egg in these two sponges is seen to be very like that of Spongilla, as described by Fiedler (5). Fiedler regards the two chromatin balls as polar bodies; but as an objection to this view it must be urged that they are formed (though not discharged) long before the egg has reached its full size.

My observation that layers similar to germ layers are developed in the asexual embryos of certain sponges recalls the account given by Dezsö (6), of the formation of buds in Tethya. Dezsö claims that these buds develop from single cells, and that in them germ layers are formed. The construction he puts upon certain cells seems, however, an arbitrary one, and I find it difficult to carry out a detailed comparison between his observations and my own. Oscar Schmidt, as Dezsö calls to mind, described in 1878, germinal layers in the buds of Loxosoma, and emphasized the biological significance of the phenomenon.

In his paper, "Zur Orientirung über die Etwicklung der Schwämme" (*Zeit. f. w. Z.*, 1875), Oscar Schmidt makes the statement that in the silicious (and horny) sponges there is no true segmentation, the ovum very early losing its cellular character. To many others besides Barrois (1) this must have seemed a remarkable statement, and it would be interesting to know if the observations which led Professor Schmidt to this view were not made on a gemmule development resembling that which I have described.

UNIVERSITY OF NORTH CAROLINA,
CHAPEL HILL, N. C., October 17, 1891.

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3. KELLER. Studien über die Organisation und Entwicklung der Chalineen. *Zeit. f. w. Z.* 1880.
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THE TRANSITION CURVE.

BY WM. CAIN, C. E.

The ideal transition curve for railroads, to pass from a tangent to a circular curve of given degree, is one whose degree of curvature is zero at the point where it leaves the tangent (P. C.) and increases directly as its length, measured along the curve from the P. C., to where it connects with the circular curve, at which point it should have the same tangent and rate of curvature as the circular curve. By the use of such curves on railroads, street-car lines, etc., to ease off the ends of circular curves, the super-elevation of the outer rail is gradually attained without shock; and the sudden change from the tangent to the circular curve so often experienced on unadjusted circular curves, with its annoying and damaging lurch, is avoided.

Mr. A. M. Wellington (see *Engineering News* for January 25th and February 8th, 1890) was the first to propose this particular curve, which he regarded as practically identical with the cubic parabola. Recently, Mr. Conway R. Howard has published in his *Transition Curve Book* an analysis of the subject founded on known principles of the cubic parabola, which this curve closely approximates to for flat arcs.

In this paper an *exact* and thorough solution of the problem will be given, which is believed to be simpler and more satisfactory every way than the approximate solutions hitherto presented.

Referring the curve above defined, to rectangular axes

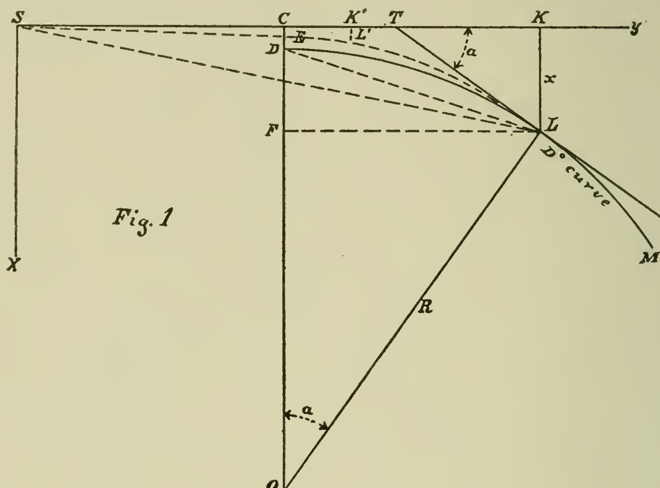

Fig. 1

X and Y (figure 1), call the co-ordinates of L, x and y, the length of curve SEL being called s. At the point $(x + \Delta x,\ y + \Delta y)$ the length of curve from $S = s + \Delta s$; the tangent at the last point making the angle $a + \Delta a$ and at (x, y), the angle a with the axis of Y. Then by the definition of curvature, the curvature at the point (x, y) is represented by limit $\dfrac{\Delta a}{\Delta s} = \dfrac{da}{ds}$ and this by the definition of the curve, must equal a constant $(2a)$ times s.

$$\therefore \frac{da}{ds} = \frac{1}{r} = 2\,as \;.\;.\;.\;.\;.\; (1);$$

whence,

$$a = as^2 \;.\;.\;.\;.\; (2),$$

since $a = o$ when $s = o$. Also from (1) $r = \infty$ when $s = o$. From the differential triangle we have,

$$dx = ds \sin a = \sin (as^2).\ ds \ldots . (3),$$
$$dy = ds \cos a = \cos (as^2).\ ds \ldots .. (4);$$

but unfortunately we are not able to integrate these expressions in finite terms, so that the equation of the curve in terms of x and y cannot be obtained.

In practice the curve SL will be run by measuring N chords of c feet each along the curve. When these chords are sufficiently short they can be regarded as of the same length as the arcs subtended by them, hence we shall always write,

$$s = Nc \ldots .. (5),$$

for the length of curve from S to any tangent point considered as L.

The degree of curve at L, $D°$ being equal to the radius of a 1° curve divided by r, we have, since the radius of a

$$1° \text{ curve} = \frac{50}{\sin (\tfrac{1}{2})°} = \frac{50}{\left(\frac{\pi}{360}\right)} \text{ (as the sines of small an-}$$

gles can be taken as equal to the arcs themselves),

$$D° = \frac{18000}{\pi r} = \frac{36000}{\pi} as \ldots .. (6).$$

To express the arc a (eq. 2) in minutes, we notice that its ratio to a semi-circumference whose radius is one, is $\frac{a}{\pi}$ and multiplying this by 180×60 we find a in minutes. Hence from (2) and (5),

$$a \text{ (in minutes)} = \frac{a}{\pi} 180 \times 60 = a \frac{180 \times 60}{\pi} c^2 N^2$$

We shall assume with Mr. Howard, no matter what the length of chord c is, that,

$$a \text{ (in minutes)} = 6\ N^2 \ldots\ldots (7).$$

This assumption is warranted by the previous equation, as a varies as N^2; hence equating these two values of a, we deduce,

$$a = \frac{\pi}{1800\ c^2} = \frac{.0017453}{c^2} \ldots\ldots (8).$$

On substituting this value of a in (6), we have,

$$D^\circ = \frac{36000}{\pi} \cdot \frac{\pi}{1800\ c^2} \cdot s = \frac{20\ s}{c^2} = \frac{20\ Nc}{c^2} = \frac{20\ N}{c} \ldots\ldots (9).$$

This is a fundamental equation of the transition curve and gives the degree of curvature at any point of the curve. Where it "connects" with the circular curve, of course D° must be the same for both curves.

By multiplying both sides of eq. (9) by $\frac{s}{200}$ we have,

$$\frac{D^\circ\ s}{200} = \frac{D^\circ\ Nc}{200} = \frac{20\ N}{c}\ \frac{Nc}{200} = \frac{N^2}{10}.$$

But a in degrees from (7) $= \frac{6\ N^2}{60} = \frac{N^2}{10}$; hence, a (in degrees) is given by the formula,

$$a \text{ (in degrees)} = \frac{D^\circ s}{200} = \frac{D^\circ\ Nc}{200} \ldots\ldots (10).$$

In figure 1 at O, the center of the circular curve DLM, having at L the same tangent and degree of curvature as the transition curve or spiral SEL, drop a perpendicular OC upon the tangent SY, cutting the spiral at E and the circular curve produced at D, and draw the chords SL and

DL. Then LOC $= a =$ LTK and $\dfrac{\text{DL}}{100} =$ number of 100 feet stations in arc DL $\therefore$ D° $\dfrac{arc\ \text{DL}}{100} =$ total angle turned in length DL $= a = \dfrac{\text{D}^\circ s}{200}$ by (10); whence,

arc DL $= \frac{1}{2}\, s = \frac{1}{2}$ length of spiral SEL . . . . (11).

From this we have, since for flat arcs, LD = LE nearly, LE = ½ SEL, or point E is nearly at middle of spiral. The distance CD = q between SY and the circular curve, may then be regarded as the offset *at the middle* of the transition curve from circular curve to tangent SY.

By aid of (9) above we can deduce two more useful formulas:

$$c = \frac{20\ \text{N}}{\text{D}^\circ} \;.\;.\;.\;.\;.\;.\; (12),$$

$$\text{N}c = s = \frac{20\ \text{N}^2}{\text{D}^\circ} \;.\;.\;.\;.\;.\; (13).$$

From eq. (3) we have, developing *sin* (as^2) by a well-known formula,

$$dx = ds\,(as^2 - \tfrac{1}{6}\,(as^2)^3 + \tfrac{1}{120}\,(as^2)^5 -, \text{etc.});$$

whence integrating and noting that the constant is zero, since $x = o$ when $s = o$, and placing for brevity a for its equivalent as^2 (eq. 2), we have,

$$x = sa\,(\tfrac{1}{3} - \frac{a^2}{42} + \frac{a^4}{1320} -, \text{etc.}) \;.\;.\;.\;.\;.\;.\; (14).$$

Developing $dy = ds\ cos\ (as^2)$ we deduce similarly,

$$y = s\,(1 - \frac{a^2}{10} + \frac{a^4}{216} - \frac{a^6}{9360} +, \text{etc.}) \;.\;.\;.\;.\;.\; (15).$$

From (8) $a = \dfrac{\pi}{1800c^2}$; hence a in eqs. (14) and (15) is given (in length of arc on a unit circle) by

$$a = as^2 = ac^2\,\mathrm{N}^2 = \frac{\pi}{1800}\,\mathrm{N}^2 = .001745329\,\mathrm{N}^2;$$

$$\therefore \log a = 7.2418774 - 10 + \log(\mathrm{N}^2) \;.\;.\;.\;.\;.\;.\;.\;.\; (16).$$

The above value of a can be obtained likewise from eq. (7). It is independent of c, as in fact was assumed from the first; but since $s = \mathrm{N}c$, the values of both x and y above, vary directly as c.

Therefore if we compute from (14) and (15) successive values of x and y for $c = 100$, corresponding to $\mathrm{N} = 1$, 2, 3, 4, . . . , 15, and denote these values by,

$$\mathrm{X}_1, \mathrm{X}_2, \mathrm{X}_3, \ldots, \mathrm{X}_{15},$$
$$\mathrm{Y}_1, \mathrm{Y}_2, \mathrm{Y}_3, \ldots \mathrm{Y}_{15},$$

the subscripts denoting the station to which they refer; then when c has any other value than 100, we have by (14) and (15),

$$x = \frac{\mathrm{X}c}{100} = \frac{0.2\,\mathrm{NX}}{\mathrm{D}^\circ} \;.\;.\;.\;.\;.\; (17),$$

$$y = \frac{\mathrm{Y}c}{100} = \frac{0.2\,\mathrm{NY}}{\mathrm{D}^\circ} \;.\;.\;.\;.\;.\; (18);$$

the last forms being derived by substituting for c its value $\dfrac{20\,\mathrm{N}}{\mathrm{D}^\circ}$ given by (12).

The results of the computation are given in the adjoining table under the corresponding values of N given at the tops of the columns.

N	1	2	3	4	5	6	7	8
X	.058178	.46542	1.57074	3.72316	7.27121	12.5628	19.9445	29.760
Y	100.000	199.999	299.993	399.969	499.904	599.763	699.488	799.002
F	.25000	.25000	.25000	.25000	.25001	.25002	.25005	.25011
Q	.002909	.046542	.235611	.744632	1.81785	3.7692	6.982	11.910
a	6′	24′	54′	1°36′	2°30′	3°36′	4°54′	6°24′
Δ	2′	8′	18′	32′	50′	1°12′	1°38′	2°07′59″

N	9	10	11	12	13	14	15
X	42.351	58.051	77.188	100.078	127.024	158.310	194.197
Y	898.201	996.958	1095.104	1192.442	1288.735	1383.706	1477.033
F	.25018	.25026	.25038	.25056	.25077	.25104	.25137
Q	19.071	29.056	42.519	60.180	82.819	111.278	146.448
a	8°06′	10°00′	12°06′	14°24′	16°54′	19°36′	22°30′
Δ	2°41′58″	3°19′57″	4°01′55″	4°47′51″	5°37′45″	6°31′37″	7°29′25″

The numerical values in the table were computed by me and checked by Mr. H. B. Shaw, so that it is believed no error exists in them.

In computing the values of X given by (14) it was found that the results could be found correctly to the last figure given, for N = 1, 2, by taking only the first term of the parenthesis and neglecting the others; for N = 3 to 11 inclusive, two terms are needed and for N = 12, 13, 14, 15, only three terms are required. For the values of Y, two terms of the parenthesis in (15) were used up to N = 9 inclusive; for greater values of N three terms only are required.

A six figure table of logarithms was used except for the larger values, where a seven place table proved desirable.

The series is very converging for the small values of a used, and in fact would answer for much larger values of a if desired; hence we see that we are concerned here with a very converging series; in fact, the same series used in computing a table of sines and co-sines, so that we can find x and y accurately to any desired number of decimal places.

The angle made by a chord from station o to station n with the axis of Y will be designated by Δ_n. This angle is readily found from the formula,

$$\tan \Delta_n = \frac{X_n}{Y_n}.$$

Thus for Δ_{12}, we have $\tan \Delta_{12} = \dfrac{100.078}{1192.44}$, whence $\Delta_{12} = 4^\circ 47' 51''$.

The angles made by the chords from sta. s to the successive stas. 1, 2, 3, ... , 12, with the Y axis are given in the previous table, and the values of $a = 6\ N^2$ (in minutes), eq. (7), are placed above for comparison.

It will be observed from this table that if we express Δ to the nearest minute that we have, except for N = 15,

$$\Delta = \frac{a}{3} = 2\ N^2\ (\textit{in minutes})\ .\ .\ .\ .\ .\ .\ (19).$$

If we include N = 15, the extreme error made by using the formula $\Delta = \dfrac{a}{3}$ is 35 seconds corresponding to N = 15, a matter of no practical importance.

If we should continue the table for greater values of N than 15, we should find the error in using (19) to increase, which explains why N = 15 is taken as the extreme limit of the table; besides we rarely have need for more than 15 stations of a transition curve. For greater values of N, (19) should not be used at all and the angles Δ must all be computed by the strict method.

The angle made by any chord connecting any two stations of the curve with the Y axis, will be designated by i with two subscripts, giving the station numbers through which the chord is drawn; thus $i_{3\text{-}9}$ indicates the angle made by the chord joining stas. 3 and 9 with the Y axis. Its value is readily found from the equation,

$$\tan i_{3\text{-}9} = \frac{X_9 - X_3}{Y_9 - Y_3} = \frac{40.7803}{598.208},$$

to be, $i_{3\text{-}9} = 3^\circ 54' 00''$. Similarly we find the inclinations of the chords, to the Y axis, connecting *any* two stations.

In the general table given at the end of this paper the values of X, Y, a, Δ and i are inserted corresponding to the stations given at the tops of the vertical columns.

[NOTE.—The general table does not give the quantities X, Y, and Q as closely as the preceding table, and the values of Δ and i in it are only expressed to the nearest minute.]

The angles given below the horizontal row Δ, are the values of i for the chords joining the stations in the vertical columns to which they refer. Thus line (2) column (4) angle $0^\circ 56' = i_{2\text{-}4}$ or the inclination of chord (2) (4) to SK.

The angle $a_5 = 2^\circ 30'$ is that which the transition curve at sta. (5) makes with SK. Also the angle between chord (5) (8) and tangent at sta. (5) $= 4^\circ 18' - 2^\circ 30' = 1^\circ 48'$ and the angle between chords (5) (8) and (2) (5) $= 4^\circ 18' - 1^\circ 18' = 3^\circ 00'$.

Similarly we can find any angle needed in running the curve.

The quantity Z of the table $= D^\circ s = 20\ N^2$, whence

$$s = \frac{Z}{D^\circ},\ D^\circ = \frac{Z}{s}, \ldots\ldots (20).$$

Line C gives the semi-chord of the arc of a 1° circular curve, of which a subtends half that arc $\therefore$ C = 5729.65 sin a. For a D° curve, divide by D° expressed in degrees and decimals.

Line Q gives the product q D°, where q is the distance CD (fig. 1) and D° the degree of circular curve LA. We find this product as follows: Call, for brevity, R_1 the radius of a 1° curve (5729.65 was used), then in fig. 1, $R = \frac{R_1}{D^\circ}$ and q = KL + OF — OD = x + R $\cos a$ — R. Therefore, from (17),

$$q = \frac{.2\ NX}{D^\circ} + \frac{R_1}{D^\circ} \cos a - \frac{R_1}{D^\circ}$$

$$\therefore Q = q\,D^\circ = .2\ NX + R_1 \cos a - R_1 \ldots\ldots (21).$$

Hence, calling the ratio of q to x (the ordinate at L) F, we have,

$$F = \frac{q}{x} = \frac{q\,D^\circ}{.2\ NX} = \frac{Q}{.2\ NX} \ldots\ldots (22)$$

from these formulas, rows F and Q of the tables were computed. It is seen that this ratio is ¼ or nearly so throughout.

From the above *exact* formulas, the table of "Equivalents" given below is made out. They are identical with the formulas given by Mr. Howard, though the latter were deduced in a totally different way.

$$c = \frac{s}{N} = \frac{Z}{D^\circ N} = \frac{20\ N}{D^\circ} = \frac{20\ Nq}{Q} = \frac{100\ x}{X} = \frac{100\ y}{Y},$$

$$s = cN = \frac{Z}{D^\circ} = \frac{20\ N^2}{D^\circ} = \frac{200\ a}{D^\circ},$$

$$D^\circ = \frac{Z}{s} = \frac{Q}{q} = \frac{20\ N}{c} = \frac{200\ a}{s},$$

$$x = \frac{cX}{100} = \frac{.2\ NX}{D^\circ} = \frac{cY}{100} \tan \Delta = \frac{Q}{D^\circ F},$$

$$y = \frac{cY}{100} = \frac{.2\ NY}{D^\circ} = \frac{cX}{100} \cot \Delta,$$

$$Q = q\ D^\circ = .2\ NXF,$$

$$q = \frac{Q}{D^\circ} = \frac{FXc}{100} = \frac{sQ}{Z} = \frac{cQ}{20\ N} = \frac{.2\ NXF}{D^\circ}.$$

In these formulas,

c = chord length between consecutive stations;

$x = \frac{cX}{100}$, $y = \frac{cY}{100}$, are the co-ordinates of stations corresponding;

s = length of curve from S to station N.

When $c = 100$, $x = X$ and $y = Y$.

TO LAY OFF THE TRANSITION CURVE.

1. *By offsets from the tangent.*

Example. Let $c = 20$, $N = 8$ $\therefore y = \frac{c}{100} Y = \frac{1}{5} Y$, $x = \frac{c}{100} X = \frac{1}{5} X$; where Y and X, for N = 1, 2, 3, . . . , 8, are to be taken from the general table.

$\therefore y_1 = \frac{1}{5}(100) = 20$, $y_2 = \frac{1}{5}(200) = 40$, $y_3 = \frac{1}{5}(299.99) = 60$, etc.;

$x_1 = \frac{1}{5}(.06) = .01$, $x_2 = \frac{1}{5}(.47) = .09$, $x_3 = \frac{1}{5}(1.57) = .31$, etc.

Having computed all the ordinates for the eight stations, measure the successive values of y along SY from S and the corresponding ordinates or offsets x, at right angles to SY, until all the stations are located.

2. *By deflection angles.*

The method is similar to that of running in a circular curve with transit and chain.

Example. Let $c = 25$, $N = 7$.

Deflect from tangent SY, with transit at S, successively, $\Delta_1 = 2'$, $\Delta_2 = 8'$, $\Delta_3 = 18'$, $\Delta_4 = 32'$, $\Delta_5 = 50'$, $\Delta_6 = 1°12'$, $\Delta_7 = 1°38'$ and measure S 1 = 25 feet, 12 = 25 feet, and so on, to fix the stations 1, 2, 3, etc.

The degree of the circular curve connecting at station 7 is, $D° = \dfrac{Z}{Nc} = \dfrac{980}{7 \times 25} = 5°.6 = 5°36'$.

If instrument has to be set at sta. (3) and the balance of the curve run in from (3), clamp vernier at $\Delta_3 = 18'$ before removing from S; then set over (3), verify reading and sight to S with angle 18′ on plate, deflect to $a_3 = 54'$ to sight on tangent if desired; then reversing telescope and taking from table, angles $i_{3\text{-}4}$, $i_{3\text{-}5}$, $i_{3\text{-}6}$, $i_{3\text{-}7}$, equal 1°14′, 1°38′, 2°06′ and 2°38′ respectively, deflect successively to these readings to locate stas. 4, 5, 6 and 7. At (7) with angle 2°38′ on plate, sight to (3) and turn off to $a_7 = 4°54'$ for the common tangent at (7). Reversing telescope, we run in the 5°36′ circular curve as usual from this tangent.

The curve is as easily run in *backwards*. Thus having run the circular curve and turned into tangent at 7, set vernier at $a_7 = 4°54'$, so that on turning to 0°00′ we sight along a line parallel to final tangent SY.

We then set vernier to angle $i_{6\text{-}7} = 4°14'$ to fix (6), $i_{5\text{-}7} = 3°38'$ to fix (5), $i_{4\text{-}7} = 3°06'$ to fix (4), $i_{3\text{-}7} = 2°38'$ to fix (3), etc. If we cannot see beyond (3), remove to (3) and with vernier reading as before $i_{3\text{-}7} = 2°38'$, sight to (7), reverse telescope and set to $a_{2-3} = 38'$, $a_{1-3} = 26'$, $a_{0-3} = \Delta_3 = 18'$ successively to fix stas. (2), (1) and (0).

Lastly, at sta. *o* or S, with last vernier reading $\Delta_3 = 18'$ on plate, sight to sta. (3) and turn to 0°00′ to sight along tangent SY.

Always set the angle off, that any chord makes with the Y axis, *on the proper side of the o point*, so that when we sight along that chord and then turn to 0°00′ the line of sight will be parallel to the tangent SY. This is best done by leaving the last angle turned clamped on plate, when we move up to a new station, at which point verify angle and *reverse* telescope to sight back to last station at which transit was set.

APPROXIMATE FORMULAS.

By referring to the general table, we see that the ordinate X at the middle of any length of curve is nearly ⅛ that at the end. Thus the ordinate $X_6 = 12.56$ and ⅛ $X_{12} = 12.51$, also $X_3 = 1.57$, and this is equal ⅛ $X_6 =$ 1.57, etc.

If we use the approximate formula $x = \frac{1}{3} as^3$, found from (14) by neglecting all terms after the first and designate by x_o the ordinate corresponding to $s_o = \frac{s}{2}$ we have

$x_o = \frac{1}{8}\left(\frac{as^3}{3}\right)$ or ⅛ the extreme ordinate x.

The equation $x = \frac{1}{3} ay^3$ is that of the cubic parabola, and we see that the eq. $x = \frac{1}{3} as^3$ closely approximates to it for the very flat arcs considered, thus furnishing the basis for the approximate solutions before referred to.

Again in fig. 1, for flat arcs, we have seen that radius OD produced, drawn ⊥ SK, nearly exactly bisects the curve SEL, hence SG is nearly equal to LD (where G is the intersection of chord SL and OD), and since arc Δ nearly $= \frac{CG}{SG}$ and arc $\frac{a}{2} =$ DLF (in arc) $= \frac{FD}{LD}$ and $\Delta = \frac{a}{3}$ we have, nearly,

$$\frac{\Delta}{\frac{a}{2}} = \frac{CG}{FD} = 2/3;$$

or since $CG = \frac{KL}{2} = \frac{x}{2} \therefore FD = 3/4\, x$,

and $DC = FC - FD = x - 3/4\, x = 1/4\, x = q$.

From the table we see that $Q = \frac{x}{q} = 1/4$ nearly throughout.

We have shown above likewise that $CE = x_0 = 1/8\, x$ nearly, and as $q = 1/4\, x$ nearly, we have, nearly,

$$CE = 1/2\, CD = 1/2\, q;$$

so that the curve SEL nearly bisects the gap q between the tangent and the circular curve.

We shall now deduce an approximate formula for finding the successive angles i in terms of N and N_1, the numbers of the stations between which the chords are drawn. Neglecting all terms of (14) after the first, and calling x^1 the approximate value of x, we have

$$\frac{x^1}{s} = 1/3\, a = \triangle \text{ (to nearest minute of arc).}$$

We should naturally infer, within this same limit of accuracy, that the arc i can be expressed by a similar approximate formula,

$$i = \frac{x_1{}^1 - x^1}{s_1 - s};$$

where $x_1{}^1 - x^1$ is the difference in the ordinates computed by the approximate formula above and $s_1 - s$ = length of arc between them.

We have just seen that this formula is true to the nearest minute of arc when x^1 and s are zero, in which case i reduces to $\triangle$, and we shall now reduce it and express i in terms of N and N_1 and test it for other values.

We have,

$$x^1 = \tfrac{1}{3}\, as = \tfrac{1}{3}\, as^3 = \tfrac{1}{3}\, ac^3\, N^3;$$

$$\therefore i = \frac{x_1{}^1 - x^1}{s_1 - s} = \frac{a}{3} \cdot \frac{c^3\,(N_1{}^3 - N^3)}{c\,(N_1 - N)} = \frac{ac^2}{3}(N_1{}^2 + NN_1 + N^2).$$

Replacing ac^2 by its value $\frac{\pi}{1800}$ (eq. 8) and multiplying both sides of the equation by $\frac{180 \times 60}{\pi}$ to reduce to minutes, we have,

$$i \text{ (in minutes)} = 2\,(N_1{}^2 + N_1 N + N^2) \;.\;.\;.\;.\;. \;(23).$$

We find that this formula is correct to the nearest minute, or as accurate as the formula $\Delta = \tfrac{1}{3}\, a$, which is correct up to $N = 14$ (and practically to $N = 15$) to the nearest minute.

In the above, N_1 has been taken as the number of the forward station and N of the one nearest S; but if the reverse obtains, on interchanging N_1 and N in the first formula, we shall arrive at the same formula (23), which is thus perfectly general and applies whichever is the forward station.

As an application compute i_{5-10}: we have, putting $N_1 = 10$, $N = 5$,

$$i_{5-10} = 2\,(10^2 + 10 \times 5 + 5^2) = 350' = 5°50',$$

correct by the general table, and in fact differs only a few seconds from the exact value.

It is more expeditious, however, to compute the successive values of i by differences. Thus, if we change N to N + 1 in (23), we get the angle i made by the chord from sta. (N + 1) to sta. N_1 with the Y axis. Subtracting (23) from this we have the angle made by the two chords, from N to N_1 and (N + 1) to N_1 equal to

1st difference $= 2\ (N_1 + 2\ N + 1)$ *minutes* . . . . (24).

As N increases one at a time, the first difference changes four at a time,

$\therefore$ 2d difference = 4 minutes.

We observe from (23) that for $N = 0$, $i = \triangle = 2\ N_1{}^2$, which agrees with (19); also for $N = N_1$, the right member reduces to $6\ N^2$, which by (7) is exactly equal to the a corresponding to the station.

Hence, starting with $N = 0$ in (23), which gives $\triangle$, and increasing N one at a time, we compute the corresponding i's until $N = N_1$ when the a at sta. N_1 is found. As N again increases one at a time, the following i's are found.

The formula (23) is found to be exact to the nearest minute, when compared with exact results, and is more nearly correct the less N and N_1 differ and for $N = N_1$ it is absolutely exact.

As an application, let $N_1 = 5$, whence first difference by (24) $= 12 + 4\ N$ and second difference $= 4$.

For $N = 0$, angle between chords 05 and $15 = 12'$.
$N = 1$, " " " 15 " $25 = 16'$.
$N = 2$, " " " 25 " $35 = 20'$.

Similarly for the others.

Starting with $\triangle_5 = 2\ N_1{}^2 = 50'$ and adding the successive differences above, we find, $i_{1\text{-}5} = 50 + 12 = 62'$, $i_{2\text{-}5} = 78'$, $i_{3\text{-}5} = 98'$, $i_{4\text{-}5} = 122'$, $i_{5\text{-}5} = a_5 = 150'$, $i_{5\text{-}6} = 182$, and so on.

As (23) reduces to a for $N = N_1$, the method of differences above evidently applies in finding a_5 from $i_{4\text{-}5}$ and $i_{5\text{-}6}$ from a_5.

We shall close by calling attention to one more interesting result. The angle i that a chord from station $N_1 - 1$ to station N_1 makes with the Y axis, is found from (23) by changing N to $N_1 - 1$ $\therefore$ $i = 6 N_1^2 - 6 N_1 + 2$. Subtracting this from the a at $N_1 = 6 N_1^2$ and we have $a - i = 6 N_1 - 2$. If we regard N_1 as the point of connection with the circular curve, we have $D^\circ = \frac{20 N_1}{c}$ and the first deflection from the tangent on the circular curve for a chord of c feet is $\frac{1}{2}\ 60\ D^\circ \frac{c}{100} = 6 N_1$ minutes. This is always greater by two minutes than the angle between the tangent at station N_1 and the chord from station $N_1 - 1$ to station N_1, as we have just found the last angle to equal $(6 N_1 - 2)$ minutes. We should naturally expect such a result from the definition of the curve.

GENERAL TABLE.

N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
X	.06	.47	1.57	3.72	7.27	12.56	19.94	29.76	42.35	58.05	77.19	100.08	127.02	158.31	194.20
Y	100.	200.	299.99	399.97	499.90	599.76	699.49	799.00	898.20	996.96	1095.10	1192.44	1288.73	1383.71	1477.03
F	.25	.25	.25	.25	.25001	.25002	.25005	.25011	.25018	.25026	.25038	.25056	.25077	.25104	.25137
Q	.0029	.04654	.23561	.74463	1.8178	3.7692	6.982	11.910	19.071	29.056	42.519	60.180	82.819	111.28	146.45
Z	20	80	180	320	500	720	980	1280	1620	2000	2420	2880	3380	3920	4500
C	10	40	90	160	250.5	359.8	489.4	638.7	807.3	994.9	1201.0	1424.9	1665.6	1922.0	2192.6
a	06′	0°24′	0°54′	1°36′	2°30′	3°36′	4°54′	6°24′	8°06′	10°00′	12°06′	14°24′	16°54′	19°36′	22°30′
Δ	02′	0°08′	0°18′	0°32′	0°50′	1°12′	1°38′	2°08′	2°42	3°20′	4°02′	4°48′	5°38′	6°32′	7°29′
	1	0°14′	0°26′	0°42′	1°02′	1°26′	1°54	2°26′	3°02′	3°42′	4°26′	5°14′	6°06′	7°02′	8°02′
		2	0°38′	0°56′	1°18′	1°44′	2°14′	2°48′	3°26′	4°08′	4°54′	5°44′	6°38′	7°36′	8°38′
			3	1°14′	1°38′	2°06′	2°38′	3°14′	3°54′	4°38′	5°26′	6°18′	7°14′	8°14′	9°18′
				4	2°02′	2°32′	3°06′	3°44	4°26′	5°12′	6°02′	6°56′	7°54′	8°56′	10°02′
					5	3°02′	3°38′	4°18′	5°02′	5°50′	6°42′	7°38′	8°38′	9°42′	10°50′
						6	4°14′	4°56′	5°42′	6°32′	7°26′	8°24′	9°26′	10°32′	11°42′
							7	5°38′	6°26′	7°18′	8°14′	9°14′	10°18′	11°26′	12°38′
								8	7°14′	8°08′	9°06′	10°08′	11°14′	12°24′	13°38′
									9	9°02′	10°02′	11°06′	12°14′	13°26′	14°42′
										10	11°02′	12°08′	13°18′	14°32′	15°50′
											11	13°14′	14°26′	15°42′	17°02′
												12	15°38′	16°56′	18°18′
													13	18°14′	19°38′
														14	21°02′
															15

THE OCCURRENCE OF PLATINUM IN NORTH CAROLINA.

BY F. P. VENABLE.

The statement that platinum has been found and hence occurs in North Carolina is made in a number of text-books on chemistry, mineralogy and metallurgy. Statements so wide-spread and often repeated naturally lead to inquiries as to where it has been found, who found it, etc. That is, upon what authority is this claim made for the State and who can vouch for, or has seen, the platinum. I have, for a year or two, carefully investigated this question, and as I seem to have gotten all the information obtainable on the subject, I venture to present it before the Society, however unsatisfactory it may be.

It will be proper here to republish the first mention in a scientific journal of the finding of platinum in the State. Among the "Mineralogical Notes" appearing in the *American Journal of Science* for 1847 (2d Series, Vol. IV, p. 280), Dr. Charles Upham Shepard reports the following:

"*Native Platinum in North Carolina.*—In November last I received in a letter from Hon. T. L. Clingman, of Asheville, N. C., a small reniform grain of native platinum, with the following remark: 'The enclosed metallic grain was given me by a friend, who says it was found among the gold of one of his rockers. It looks like platinum.'

"Its weight was 2.541 grs. There was no difficulty, by means of its physical and chemical properties, in identifying it with the substance above suggested. Its specific gravity = 18. In a subsequent letter, dated January 3d (written before receiving my reply), Mr. C. adds still farther: 'Mr. T. T. Erwin, who presented it to me, says that his overseer, in whose veracity he has the fullest confidence, gave it to him with the gold obtained from the rocker, and that he (Mr. Erwin) does not entertain the smallest doubt of its having been found in his mine in the north part of Rutherford county. Should it prove to be platinum, it is of interest to me as the first specimen of that mineral found in the United States.'

"Fearing, however, that the grain might have originated in a foreign locality, I addressed particular inquiries to Mr. C. on this head and received from him the following additional statements: 'The platinum specimen formerly sent you was taken from the gold rocker by Mr. Lyon, the overseer of Mr. Erwin. Mr. L. is a man of good character, and all persons who know him entertain no doubt whatever of his having obtained the specimen as represented. Mr. L. had no suspicion of its being anything more than silver, which was known to be found with the gold. The place at which he obtained it was in Rutherford county, near the line of the new county of McDowell. I would have sent you his certificate, but I had no doubt that other specimens would be found. In fact, almost every miner to whom I described it said he had seen just such specimens, but they had supposed them to be fragments of steel or iron that had been broken from the edges of the mining tools.'"

In a foot-note referring to the above, Dr. Shepard adds the following statements. The foot-note is headed:

"*Bismuthic Gold.* In the letter from which the above is extracted, was forwarded to me a few grains of which the largest weighed only 0.907 grains of an alloy of bismuth and gold, to which faint traces of mercury were adhering. Concerning their origin, Mr. C. observes: 'They were brought me by a friend, Mr. Willis, under the impression that they might be platinum. They were mixed with the gold of several days' work, and I assisted him in picking them out from a parcel he brought to the bank in this place. They are evidently not grains of platinum.' "

A description of the grains is given: Structure, subfibrous; Hardness = 2.5 — 3.0; Gr. = 12.44 — 12.9; color that of palladium; malleable, etc.

I think most will agree with Prof. E. S. Dana, who writes, in a letter regarding the above note of Dr. Shepard: "The evidence upon which the statement rests, you will see, is not very conclusive."

I have been unable to find anywhere, either personally or through friends who have kindly searched for me, any other publication of a definite kind of platinum. All other public mention seems to refer to or rest upon the one given above.

In his Geology of North Carolina, Vol. I, Dr. Kerr says on page 55 of his appendix:

"The occurrence of grains of platinum among the sands of gold-washings of Rutherford and Burke counties was first brought to notice by General Clingman, who sent half a dozen grains from a mine near Jeanestown to Prof. C. U. Shepard. It has also been found on Brown Mountain, in Burke, according to the information received from Mr. E. Bissell. It is reported as having been found near Burnsville, Yancey county."

These statements are copied in all subsequent reports on the Minerals of North Carolina. Even in the last report by Prof. Genth, published as a Bulletin of the United States Geological Survey, No. 74, 1891, the same wording is followed, but Prof. Genth adds, "Hidden, after much searching, failed to discover platinum at any of the reported localities." As to palladium, which Dr. Kerr reports also as occurring in Burke and Rutherford, Genth says "very doubtful."

Taking Dr. Kerr's statements about platinum in detail, the first must refer to the account already quoted of Shepard's identification of one grain sent him by Clingman. I can find no account of other finds. Nor is any published mention to be found of Bissell's discovery. There is no record of a scientific examination nor any scientific authority supporting it. Mr. Bissell is himself long since dead. There is the same lack of authenticity and scientific authority for the report from Burnsville.

It is a great pity that these reports, etc., were not examined into and definitely settled as to authenticity while those finding or acting as experts were yet alive. Dr. Shepard seems to have left no trace of his connection with the find beyond the note quoted.

Something so unique as the only specimen of native platinum found in the United States up to that time would surely have been preserved in his collection of minerals, yet Prof. Harris, of Amherst, where the collection is preserved, writes me that there is no record of it there.

General Clingman, now very old, has kindly written me his recollection of the matter:

"In the year 1846 I found platinum in the gold washings of Rutherford county, and sent specimens to Prof. C. U. Shepard, then in Charleston, S. C., and part of the year in Connecticut. I also sent some to Prof. Dana. It was found in small pieces among the gold grains. I also obtained some in McDowell and in Burke, also some in the western part of Rutherford, now Polk county, and a little in the eastern part of Henderson county, near the Polk line. I am told that some was also found in the southern part of Jackson county in the washings of the Gold Spring tract."

Prof. E. S. Dana has written me that his father, Prof. J. D. Dana, who is referred to above by General Clingman, "has no recollection in regard to the subject."

Dr. F. A. Genth, who has done so much for the mineralogy of the State, and is so thoroughly conversant with it, writes:

"I regret that I cannot give you any additional information about the occurrence of platinum in North Carolina. I have no personal knowledge of any find, and it seems that General Clingman is the only person who can authoritatively speak of its occurrence. I would like very much to see and examine some of the grains which he is said to have sent to the late Prof. Shepard."

Dr. C. D. Smith says: "I do not know of the occurrence of platinum anywhere in the State. Many years ago it was claimed to have been found in some gold placers in the Piedmont region of the State. I, however, have no knowledge of just ground for such claim. I very much desire that it might be found in North Carolina." Dr. Smith has spent his working years among the minerals of Western North Carolina and has had every opportunity of hearing of such a find if one had been made.

Mr. Edison was attracted by the reported occurrence of platinum here and hoped to find a source of supply of the costly metal for his incandescent lamps. He advertised for large quantities, hoping thus to stir up private investigators, and at the same time sent trained experts to look for it. The following brief note, received from his laboratory, gives the results:

"Mr. Edison has instructed me to inform you that his assistants panned in every gold stream in North Carolina without ever getting a color of platinum."

Mr. Hidden, who was one of these assistants, has given me a short account of his investigations:

"As to platinum in North Carolina and my search for veins of it in 1879: The localities visited comprised those mentioned in 'Dana,' and nearly all the 'placer gold diggings' of North Carolina, South Carolina, Georgia and

Alabama. I was most thorough in and around Rutherfordton and up to Jeanestown and Brindletown. The lamented Prof. Kerr gave me personal instruction at the time, and through him I learned of the Shepard 'find' (of a few small nuggets of platinum), at a place near to 'old Whitesides settlement,' not far from Golden P. O., Rutherford county. Neither panning nor chemical tests showed any platinum in the concentrations of the auriferous gravels wherever operated. * * * I found no platinum on Brown Mountain. I know of no authentic finds of platinum in North Carolina and have no knowledge of any outside of the Clingman-Shepard statements, which are so universally quoted as facts.

"Do not understand me as believing for a moment that platinum does not exist in North Carolina, but only that I do not know of such occurrence. The extraordinary development of chrysolite-serpentine rocks in North Carolina may yet be shown to contain platinum in commercial quantity—who knows? When a nugget of platinum can be found enclosing a large per cent. of chromite, as was the case near Plattsburg, N. Y. (Collier), I begin to think that the chromite deposits of North Carolina may be profitably searched for the now very valuable metal.

"In 1879 I saw a good deal of lead (weathered bullets and shot) that passed as platinum from the gold gravels, but I repeat that I saw no platinum."

I have presented all the information that I can get on the subject. Only one scientific examination of the reported finds seems ever to have been made, and that of one grain "given by a friend" to General Clingman and sent by him to Dr. Shepard.

It is exceedingly strange that the other "finds" reported were not subjected to the examination of an expert, and that the specimens cannot be found in the museums of the country. General Clingman's reports would show it to be widely scattered through the gold region of the State. If so, some ought certainly to have been found since. Finds are indeed frequently reported now, but the grossest mistakes are made. Is it not probable that General Clingman was mistaken?

One cannot deny that platinum may occur in North Carolina, but the evidence for it is very slight. And this is said without any intention of throwing discredit upon General Clingman, who has done so much to make known to the world the mineral resources of the State.

REPORT OF TREASURER FOR 1891.

Received from fees of members	$ 68 00	
Received from fees of associate members	6 00	
Received from sales of Journals	1 50	
Received from contributions	105 00	
	$180 50	
Expended for postage		$ 14 45
Expended for express		50
Expended for binding		1 20
Expended for lamps, etc.		30
Expended for printing		118 27
		$140 48
Balance on hand		40 02
		$180 50

COUNCIL MEETING.

The reports of officers were accepted and approved.

The following officers were elected for 1892:

President	J. A. HOLMES	Chapel Hill.
First Vice-President	W. L. POTEAT	Wake Forest.
Second Vice-President	W. A. WITHERS	Raleigh.
Third Vice-President	J. W. GORE	Chapel Hill.
Secretary and Treasurer	F. P. VENABLE	Chapel Hill.

RECORDS OF MEETINGS.

SIXTY-THIRD MEETING.

PERSON HALL, September 15, 1891.

14. Preparation of Pure Zirconium Chlorides from North Carolina Zircons. F. P. Venable.

15. The Alexander County Meteorite. S. C. H. Bailey.

16. Additions to the List of Birds Found in North Carolina. Smithwick.

17. Phosphorescent Bacilli. H. V. Wilson.

18. Theorem of Least Work. Wm. Cain.

The Secretary reported 553 books and pamphlets received since the last report and thirteen additional exchanges.

SIXTY-FOURTH MEETING.

WAKE FOREST COLLEGE CHAPEL, October 23, 1891.

19. A North Carolina Catalan Furnace. H. L. Harris.

20. Twilight in High Latitudes. J. F. Lanneau.

21. The Development of Certain Sponges. H. V. Wilson.

22. Rain-making Experiments. L. R. Mills.

23. Notes on the Fertility of Physa Heterostropha Say. W. L. Poteat.

24. Drudgery in Science. F. P. Venable.

SIXTY-FIFTH MEETING.

PERSON HALL, November 17, 1891.

25. The Sun's Way. J. W. Gore.

26. A New Cosmic Theory. Chas. Baskerville.

27. A New Theory of the Origin of Petroleum. R. B. Hunter.

28. Metschnikoff's Theory of the Action of Phagocytes in Disease. H. V. Wilson.

The Secretary reported the receipt of 231 books and pamphlets and also the following new exchanges:

COLORADO—College Studies.

BUFFALO—Society of Natural History.

HAMBURG—Landwirthschaftliche Rundschau.

DUBLIN—Royal Irish Academy.

ROMA—Rassegna delle Scienze Geologiche.

Societé Francaise de Botanique.

MARBURG—Gesellschaft z. Beforderung d. Naturwissenschaften.

SIXTY-SIXTH MEETING.

PERSON HALL, December 8, 1891.

29. The Tunnel Under the St. Clair River. H. B. Shaw.

30. Does Platinum Occur in North Carolina? F. P. Venable.

31. Some Cercosporæ from Alabama. Geo. F. Atkinson.

32. Transition Curves. Wm. Cain.

The Secretary reported 108 books and pamphlets received.

The total number now in the library is 8,778.

The following additional associate members have been enrolled:

ANDREWS, A. B., Jr.,	ELLIS, CASWELL,
BASKERVILLE, CHAS.,	HARRIS, H. L.,
CONNOR,	HUNTER,
EDWARDS, A. J.,	RONDTHALER,

SMITH, T. C.

A report of the Council Meeting was read, announcing the election of officers for the year 1892.