ART. L.—*Abstract of some Paleontological studies of the Life History of SPIRIFER LÆVIS H.*; by Professor H. S. WILLIAMS, of Cornell University.*

A CAREFUL study of the character and mode of occurrence of *Spirifer lævis* H., of the Portage group of New York State, and comparison of it with other species of the genus, has led to the observation of some interesting facts bearing upon the probable history of the species in geological time. The original article embodying the results of my study was read before the Cornell Philosophical Society last spring. Only a brief abstract of some of the important points will be attempted in the present article, hoping at some future time to publish the results in full detail.

The important characters of the species were gathered under seven heads, each of which could be examined and compared separately with like characters in other species.

These were: (1) Form and proportions of the shell; (2) the size; (3) the prominence and over-arching of the beak; (4) the short and high cardinal area; (5) the triangular aperture covered by an arched pseudo-deltidium; (6) the smoothness (not plicated) of the surface; (7) the concentric series of minute radiating lines covering the surface.

A careful determination of these characters as found in *Spirifer lævis* was made, and the last character was specially noted and described.

These concentric series of fine radiating lines have not been recorded as characteristic of the species, and so far as I know have not been observed by any writers on the Devonian Brachiopods. Nevertheless it is an all-important character to be ob-

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served in making comparison with other forms. After pointing out the specific characters of *S. lævis* I give the results of a minute comparison of them with those of *S. fimbriatus* of the Hamilton and earlier formations.

This comparison has left little doubt that a genetic relationship exists between *S. lævis* and the earlier form, *S. fimbriatus*.

Then an examination was made of the relationship of several species of the preceding geological formations to the typical form as characteristic of each of the former species, and thus representatives of the type were discovered in each of the fossiliferous formations back to the Niagara.

In the Niagara group was found the earliest trace of the combination of characters found to be essential in *S. lævis* and *fimbriatus* and the other representatives seen in the intermediate formations.

The species which appears to be the central type of the original primitive species is *Spirifer crispus* Hisinger, of the Niagara formation, of which I presume *S. bicosatus* H. may be regarded but an extreme variety, and *S. sulcatus* His. (at least in part as referred by Hall), the extreme variety on the other side. The peculiarities of this species (*S. crispus* His.) are *very great abundance* and *wide distribution* in the formation in which it first appears. It being a characteristic species of the formation wherever represented, in England and at several localities in Europe.

Where it does appear, it also assumes *great variation of characters*, so that the three species in America, *S. crispus*, *S. bicosatus* and *S. sulcatus*, while good species in small collections, are recognized, even by Hall as bordering on each other in some of their varietal forms.

Also the three species recognized by Davidson in Great Britain (*S. sulcatus*, *S. elevatus* Dalman and *S. crispus*), corresponding in the main to the extreme forms identified by Hall in this country, are regarded by Davidson as doubtfully distinct species (see Brit. Sil. Brach., pp. 91 to 98) on account of the variations and intermediate forms. I have also traced out, as well as the limited material at hand would allow, the relationship to *S. glaber* Martin and other Carboniferous forms.

The study of the facts has led me to the following conclusions. Whatever theoretical description we may give to species, here are, in the first place, an abundance of individual organisms whose remains are found in the Upper Silurian rocks of Europe, Great Britain and America, presenting a few clearly marked distinctive characters, which are found variously developed in the individual forms, but so grading in the various varieties as to cause careful naturalists to associate them as varieties of a single species. There are well marked typical

characters distinguishing all the individuals from other forms of the same genus, together with great variability of the characters themselves. In the upper part of the Upper Silurian we find the same typical characters, with a greater permanence of one or other of the variations; but still, in the variations occurring later in the Corniferous and Hamilton, we have the main type represented with some variations strongly marked and seeming to be fixed, but still recognized as varieties simply.

In the Portage, we see under peculiar conditions a solitary race of the type with greatly exaggerated size, a luxuriant form, but still presenting the typical characters of the second varietal type.

In the Carboniferous we meet with several well marked varieties, but no feature which did not appear in the early form except large size, which is evidently a mark of good nourishment and other good conditions of growth. This latter seems to be a character of most of the Carboniferous forms of Brachiopods which have lived on from earlier times. There may be unknown characters to distinguish these forms, but of the characters that are preserved we have evidence that in the earliest form, the type, *S. crispus* His. of the Niagara, etc., are found all those which afterward appeared in the later representatives.

These characters appeared in combination in a single group of individuals, living in one class of conditions, in such circumstances as seem to warrant our calling them one physiological species in the sense of being able fertily to cross with each other, this being the explanation of the gradation of one form into the other noted by Davidson. This presumed—that we had a single species to begin with—we have, by intercrossing and by local conditions modifying the offspring, well defined groups, which would be called races if we knew their history but which are called species because they appear at so widely divided geological periods.

These separate groups, however, *develop no new characters*, but in those appearing at each stage are seen fixed and apparent only varietal characters of the original form, with such modifications as poor, or rich, or variety of food give to animals we now may modify. There is nothing of a specific character evolved in this series of forms which did not appear in the first forms, but, there is every evidence for the belief that the species has lived through this long geological time without losing its character, and that all that has resulted from great time and change of conditions has been the fixing into race groups of the original variable characters of the species.

The species, at its first appearance in the Silurian presented a decidedly new combination of characters for the genus and

also much variation. When once these specific though variable forms appeared, they lived till the variations which could be played on them were exhausted; and the species ceased to live and became extinct either near the close of the Carboniferous or not till later in the Mesozoic.

Some of the races or varieties may die out but they reappear again and again till there are such strong contrasts that it is difficult to see even generic resemblance between them.

The following is a tabular view of the relations of the Silurian and Devonian forms of which *Spirifer crispus* of the Niagara in New York is the type; the tracing of the history through the European forms and higher into the Carboniferous is reserved for further study. In the table, lateral extension is expressive of the morphological variations; each line represents one of the geological formations, which are arranged in their natural order; and the name of each species is placed in the position on the line representing its supposed relation to the typical form of *Sp. crispus*.

Chemung			-----	prematurus	---	
Portage			-----	lævis	-----	
Hamilton			-----	fimbriatus	----- subumbona	
Corniferous			-----	fimbriatus	-----	
Oriskany			-----	tribulis	-----	
		{ N. Y. & Tenn.	Saffordi (pars.)			
Lower Helderberg		{ Maryland		-----	octocostatus	----- modestus
		{ New York	-----	cyclopterus (pars.)	-----	
		{ New York	-----	vanuxemi	-----	
Niagara	{ shale		-----		-----	crispus
	{ limestone	-----	sulcatus (pars.)	-----	crispus	bicostatus