should not be more than four or five days, though it might be less, because of some variability in the length of the oestrus cycle, as well as in that of gestation. Such a course of events might explain the cases in which some of the young of the same litter are much smaller than the rest.

On the other hand, if ovulation occurred after the reestablishment of the uterine lumen, the birth of full-term young about sixteen days after the previous litter might be accounted for, though I have found no reports of such cases. However, since implantation would not occur until the fifth day, that is, until after parturition, in such cases, they could not be considered true cases of superfetation, unless the onset of pregnancy were counted from fertilization rather than from implantation.

In the cases cited by King[5] and Sumner[6] in which from twelve to fourteen days elapsed between two consecutive litters it is conceivable that the first pregnancy may have been confined to one horn of the uterus and that subsequent ovulation resulted in implantations in the other horn, a possibility which was suggested by King.

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## DETERMINATE EVOLUTION IN THE GENUS SPIRIFER

SINCE March, 1920, the writer has engaged in a study of variation and evolution in two groups of organisms belonging to the inclusive brachiopod genus *Spirifer*. Work first was done at the Walker Museum of the University of Chicago, and from September, 1926, to September, 1928, at the University of Cincinnati, under a National Research fellowship in the biological sciences. Since the latter date, results have been correlated and a manuscript report prepared which will be published by the Wagner Free Institute of Science of Philadelphia.

The Linnaean species *Spirifer orestes* Hall and Whitfield and *S. hungerfordi* Hall comprise two widely divergent groups within the genus *Spirifer*. The former fall within the *Aperturati* of Hall and Clarke, which include the genotype, *S. striatus* (Martin); the latter are rather primitive members of the section or subgenus *Choristites* Fischer. Both are characteristic of the uppermost Devonian (Hackberry) strata of Iowa, though closely related forms (kindly loaned by Dr. C. R. Stauffer) are found in the Martin formation of Arizona.

Since the description of *Spirifer hungerfordi* by Hall,[1] and *S. orestes* by Hall and Whitfield,[2] paleontologists have recognized that these two Linneans exhibit considerable variation or speciation, but no serious published effort has been made to distinguish them. Even in our account of the Hackberry fauna,[3] Mrs. Fenton and I merely called attention to the existence of such speciation and illustrated a few examples.

This study began, therefore, with a careful taxonomic revision, little attention being given to evolution. In the *Spirifer orestes* group (here designated a *phratry*) this revision is based primarily upon the striae, nodes and pustules which form the minute ornament of the shell, since they have been found to be much more reliable than gross characters of shape, plications, sinus or fold. In the *S. hungerfordi* gens, however, the minute ornament is essentially uniform, so that gross characters must be relied upon. In consequence, there is some discrepancy between the taxonomic units determined in the two groups, those in the former being much the more precise.

Although work at first was concentrated upon pure taxonomic differentiation, it soon became evident that the taxonomic units, when arranged stratigraphically, automatically were arranged in apparently determinate evolutionary series, distinct, parallel or homeomorphic, and non-contemporaneous. The existence of such series and a provisional interpretation of them were reported in June, 1926, although not published until 1927.[4] In September, 1926, a collection of about six thousand additional specimens, with exceptionally precise data, was secured from the late Mr. C. H. Belanski. Work was begun *de novo*, even the taxonomic units previously determined being put aside. They at once reappeared, however, as did the evolutionary series; and again it was found that series based only on characters of surface (in the *Spirifer orestes* phratry) showed regularly correlated changes in form and character and number of plications. The situation may be summed up as follows.

In the *Spirifer orestes* phratry, the primitive surface ornament consists of minute, subradial to oblique ridges or striae, which are not broken and which bear neither nodes nor pustules. In every one of the divisions (gentes, subgentes, species) into which the phratry may be divided there is an apparently determinate evolution of these striae involving three or

[5] H. D. King, "Some Anomalies in the Gestation of the Albino Rat (*Mus Norvegicus Albinus*)," *Biol. Bul.*, 24, 1913.

[6] F. B. Sumner, "Notes on Superfetation and Deferred Fertilization among Mice," *Biol. Bul.*, 30, 1916.

[1] *Geol. Iowa*, 1 pt. 2: 501, pl. 4, figs. 1a–k, 1858.

[2] *Ann. Rep. N. Y. State Cab. Nat. Hist.*, 23: 237, pl. 11, figs. 16–20, 1873.

[3] "Stratig. and Fauna of the Hackberry Stage of the Upper Devonian," 1924.

[4] *Univ. Chicago Abs. of Theses*, sci. ser. 5: 223–226, 1927.

more of the following steps: (1) primitive, continuous striae; (2) constriction of the striae, occasionally accompanied by swelling, resulting in the formation of nodes; (3) further constriction of these elevations, resulting in rows of round, generally hollow pustules; (4) loss of definite arrangement in these pustules, at least marginally; (5) enlargement of these scattered pustules into short spines. These stages are accompanied by a reduction, relative or actual, in the width of the shell, a consequent increase in tumidity, a reduction in the number and strength of the plications and (generally) a marked increase in the number of growth lamellae.

The progress of evolution, especially in forms which reach stage 4 or 5, may be traced minutely in the ontogeny of the shell. Moreover, there commonly is a close relationship between the duration of a stage in the evolution of a given line and its duration in the life of an individual, as measured in the amount of shell surface on which it is evidenced.

In spite of the regularity of these trends, they are not contemporaneous. One group, in an advanced stage of pustulation, will be contemporaneous with another in which stage 2 has been reached, and a third in which striae are primitive and continuous. In every line advanced stages of evolution, both in striae and gross characters, are followed by disappearance, and disappearance also is non-contemporaneous. These facts, plus a lack of evidence of progressive environmental change, negate the theory of natural selection, while the uniformly determinate, even predictable, nature of the changes, militates against heterogenesis.

It seems, therefore, that in the *Spirifer orestes* phratry we have numerous, parallel examples of determinate or orthogenetic evolution, operating independently of the environment and resulting regularly in extinction of the lines affected. Such evolution commonly is interpreted as racial senescence, although that theory generally has involved such factors as gigantism, multiplication of structures and extreme spinescence, which are lacking in the *Spirifer orestes* phratry.

There are several lines of evidence, however, which support Child's hypothesis of racial senescence through heritable, cumulative decrease in the rate of basal metabolism as an interpretation of these evolution trends.[5] One is the minute correlation between ontogeny and phylogeny, which strongly suggests a community of cause. Another is the fact that phylogerontic members of any given line more commonly show injury than do phyloephebic ones, and have repaired those injuries much less effectively. In the latter, valves fractured during neanic growth may be so well repaired that the injury is not shown ephebically, while in the former, injuries too small to be distinguished clearly commonly distort the entire shell. Finally, phylogerontic forms seem to have been extremely susceptible to physiologic disturbance, their shells bearing abundant and pronounced growth lamellae and constrictions. These, like incapacity for repair, seem to indicate a lowered metabolism in the organisms concerned.

[5] "Senescence and Rejuvenescence," 193–194, 463–464, 1915.

Evidence gleaned from the *Spirifer hungerfordi* gens is less conclusive regarding precise trends than is that from the *S. orestes* phratry. On the other hand, it is quite as definitely negative toward theories of selection and environmental influence, since widely divergent groups develop contemporaneously in the same spots. Evidence from injury, repair and growth disturbance is virtually identical and affords the best indication that a common evolutionary process underlies the divergent trends just mentioned.

From the evidence here briefly summarized, a theory of the racial life cycle is advanced which may be stated as follows.

Stages in the life history of a race may approximate those in that of the individuals composing it, and in such cases, rest upon the same physiologic basis. Changes involved in racial origin, in such series, find their cause in genetic variations which increase the metabolic rate; those of differentiation and decline (racial senescence) in heritable variations which reduce that rate.

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## CHANGES OCCURRING IN STORED ALCOHOLIC PLANT EXTRACTS[1]

PHYTO-CHEMISTS have used the alcoholic preservation method for the storage of plant materials for a considerable number of years. Surprisingly small, however, is the amount of work that has been done to explain the reasons for each step, and practically nothing has been done to check the effects of such a procedure on the various constituents to be estimated. There are such statements as, "Preserved in 80 per cent. alcohol," and "Calcium carbonate added to neutralize the acidity," and theoretical considerations are found to justify such statements. As previously stated, it is very hard to find analytical data to explain the reason for these steps. It is coming to be recognized that nitrogen fractionation must be completed on water extracts. A previous paper[2] from

[1] Published with the permission of the director of the Oklahoma Agricultural Experiment Station.

[2] J. E. Webster, "Effects of Storage on Alcoholic Extracts, I. Amino Acid Changes," *Plant Phys.*, 4: 141–4, 1929.