THE EMBRYOLOGY OF SAGITTARIA LANCIFOLIA L.

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We have been accustomed to base our ideas of the close or distant relationship of species, genera and families on external characters but some of the recent literature on embryological subjects has indicated that the life histories and development of species which are apparently closely related may be quite different. Johnson* calls attention to the wide variations that occur in the development of the tapetum, megaspore, embryo-sac and endosperm in the genera of a single family. In my recent paper on the Cuban *Nymphæaceæ*† I called attention not only to the difference in character of the endosperm but also to differences in the development of the embryos. This difference was especially interesting in the case of our northern *Nymphæa advena* and the Cuban *Nymphæa* which is either a different species or a variety, although the external differences are by no means conspicuous. In the light of these recent investigations it becomes interesting to know to what extent we may expect these differences in the internal life history of the more or less closely related species and also to know whether these differences co-ordinate with the external differences. This presents the questions: Are embryonic characters valuable in the separation of species? Are they of phylogenetic importance?

Recently the author accepted an opportunity to make a study of *Sagittaria lancifolia* L. for the purpose of comparison with *S. variabilis* Engelm. (now known as *S. latifolia* Willd.) as studied by Schaffner‡.

Sagittaria variabilis is distributed throughout the greater part of North America except the extreme north and extends to Mexico and Florida, while *S. lancifolia* is distributed from Delaware southward and throughout the West Indies. The two species overlap in geographical distribution in the southern part of the north temperate zone; *S. variabilis* extending much farther north and *S. lancifolia* much farther south. Externally these two species present very striking differences especially in character of the leaves and fruit as shown by the following comparison:

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*Johnson, D. S.—Seed Development in the Piperaceæ and its bearing on the Order. Johns Hopkins Univ., Cir. 178. 29–32. 1905.

† The Embryology of some Cuban Nymphæaceæ. Botanical Gazette, 42: 376–392.

‡ Schaffner, J. H.—Contribution to the Life History of Sagittaria variabilis. Botanical Gazette 23: 252–273, 1897.

SAGITTARIA VARIABILIS.	SAGITTARIA LANCIFOLIA.
1. Monoecious or sometimes dioecious.	1. Monoecious.
2. Leaves sagittate, variable in form and size, sometimes broader than long, 15–40 cm. long, basal lobes, ovate or lanceolate, acute or acuminate.	2. Leaves not variable, 4–9 dm. long; leathery, broadly linear or elliptic, acute.
3 Scapes 3–6 dm. long, angled, simple or branched.	3. Scapes 6–20 dm. long, simple or branched.
4. Filaments not dilated, glabrous.	4. Filaments not dilated, pubescent.
5. Mature heads 1.5–3 cm. in diameter.	5. Mature heads 1 cm. in diameter.
6. Bracts 1.5 cm. long, glabrous, acute or acuminate.	6. Bracts ovate or ovate-lanceolate, 1–2.5 cm. long, acute or acuminate.
7. Flowers 1.5–2.5 cm. broad.	7. Flowers 1–2.5 cm. broad.
8. Achenes obovate, about 2–4 mm. long, erect, undulate winged; beak ascending or recurved.	8. Achenes cuneate or obovate, 2–3 mm. long, winged; beak short, ascending.
9. Summer and fall.	9. Spring and summer.

With such striking external differences one would naturally expect equally interesting internal differences but to my surprise I found the development of the embryo-sac and embryo of *S. lancifolia* practically the same as had been described by Schaffner for *S. variabilis*. The comparison with Schaffner's results will be brought out in the following discussion.

EMBRYO-SAC.

The author was unable to determine the origin and development of the archesporium satisfactorily but traced without difficulty, the deveropment of the embryo-sac beginning with the one-nucleate stage (Fig. I). In the formation of the two-nucleate (Fig. 2) stage the sac elongates to twice the length of the one-nucleate stage. Schaffner did not secure material for these two stages but from this point on the development of the embryo-sac of the two species is exactly the same, except that I was inclined to believe the antipodals in *S. lanceolata* not quite so presistent as he found them in *S. variabilis*.

ENDOSPERM.

The development of the endosperm follows exactly the same course as that of *S. variabilis* as described by Schaffner. Schaffner did not fully understand the significance of the lower endosperm

nucleus but advanced the idea that it might "play an important part in the transfer of food material from the funicular region, beyond the antipodals, to the cotyledons, and especially in facilitating the formation of the cap of endosperm which covers the tip of the cotyledon." This idea has been supported by my papers on the *Nymphæaceæ** in which I found similar structures and by Ikeda†, who demonstrated the antipodals to be in the course of the food supply in certain species of *Liliaceæ*. In *S. lancifolia* I find further evidence in favor of this view; in many instances the antipodals disappear and this part of the sac is extended into a pocket-like structure (Fig. 3) in which we find a mass of protoplasm extending to the lower endosperm cell. At this time the embryo (Fig. 17) was well advanced.

Embryo.

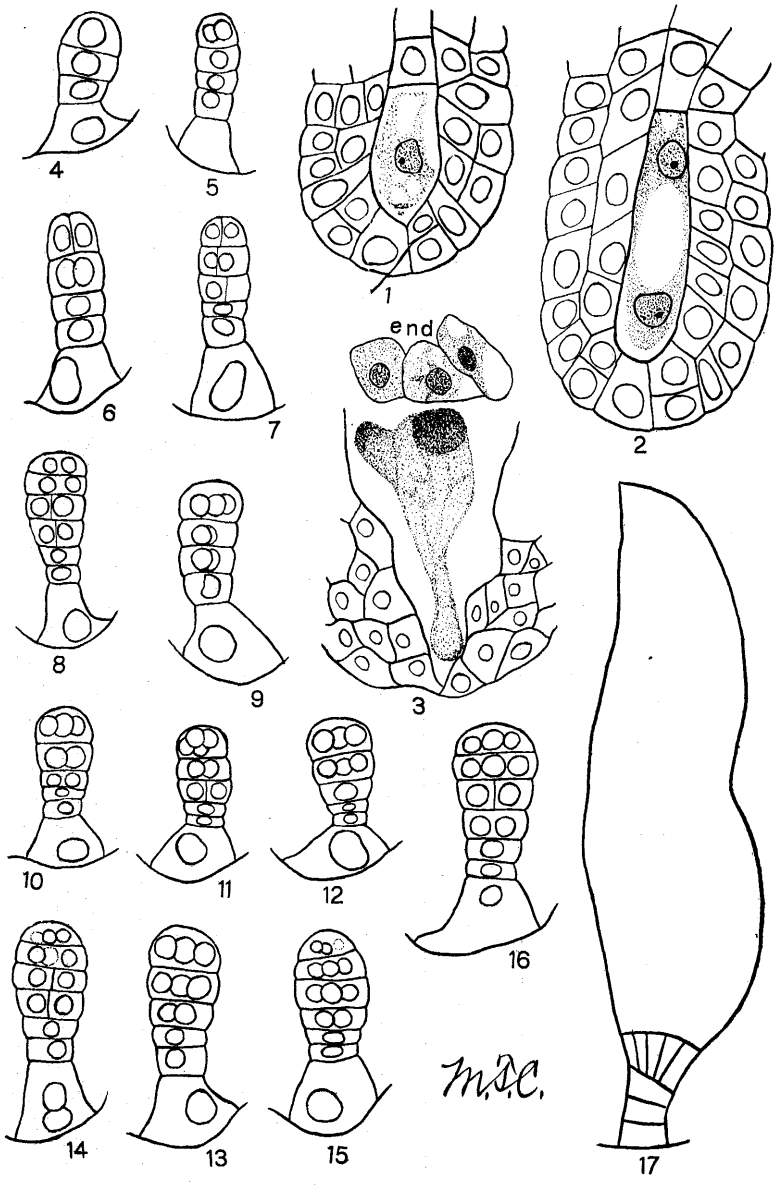
Although the author did not secure the very youngest stages of the embryo, after examining a large number, it seemed evident that the embryo had followed exactly the same line of development as the embryo of *S. variabilis*. The elongation of the embryo was due to the repeated division of the cell next to the suspensor. By the time four cells in addition to the large suspensor cell had been formed, the apical cell divided by the formation of a longitudinal wall (Figs. 5, 6). After this the longitudinal divisions were found to be somewhat irregular (Figs. 7 to 16). The longitudinal cell walls were frequently very indistinct but the number of cells could be ascertained by counting the nuclei of the serial sections. My material was unsatisfactory for making a study of the more advanced stages of the embryo but it apparently followed the same course of development as *S. variabilis*.

From the facts herein presented it appears that the internal and external characters do not necessarily co-ordinate. In the case of *Nymphæa advena* of the north and the *Nymphæa* ——— of Cuba which so far as external characters are concerned are strikingly similar the embryos show considerable differences, while in the case of *S. variabilis* and *S. lancifolia* the external characters are strikingly different and the embryological characters are practically the same. But we are now confronted by a new question which can only be answered by future investigations: Are the embryological characters of the plant more or less plastic than the external characters?

* The development of the Embryo-sacs and Embryos of Castalia odorata and Nymphæa advena. Bull. Torr. Bot. Club. 24: 211–220.

† Ikeda, T.—Studies in the Physiological Functions of the antipodals and Related Phenomena of Fertilization in Liliaceæ. I. Trycirtis hirta Bull. Coll. Agri. Tokyo Imp. University. 5: 41–72. 1902.

OHIO NATURALIST. *Plate VIII.*



COOK on "Embryology of Sagittaria."

The material for this paper was collected in a lagoon near San Antonio de los Banos, Havana Province, Cuba. Herbarium specimens have been deposited in the herbarium of the New York Botanical Garden.

ESTACION CENTRAL AGRONOMICA,
Santiago de las Vegas, Cuba.

EXPLANATION OF FIGURES OF PLATE VIII.

Fig. 1. Functional megaspore.
Fig. 2. Two-nucleate embryo-sac.
Fig. 3. Antipodal end of sac in which the antipodals have disappeared; end.—endosperm. Same age as embryo in Fig. 17.
Figs. 4 to 16. Series of embryos.
Fig. 17. Outline of embryo same age as Fig. 3.