**On the Different Views hitherto Proposed
regarding the Morphology of the
Flowers of *Ginkgo biloba* L.**

(*Preliminary note.*)

By

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(*Continued from No. 109, p. 15.*)

With Pl. I.

The most noteworthy recent work including the general morphological questions of *Ginkgo* flower is CELAKOVSKY's "Die Gymnospermen. Eine morphologisch-phylogenetische Studie." His views in regard to the morphology of *Ginkgo* flower are as follows:—The so-called seed-stalk of *Ginkgo* is a shoot that arises, as in *Araucariaceæ*, in the axil of a bract and serves as the flower-axis, producing usually two, but sometimes four decussate carpels. Each carpel is greatly reduced, its terminal portion being transformed, after the manner of *Cycas*, into a single ovule, and this terminal portion is alone developed; and very rarely (that is, in flowers with four ovules) the stalk-like basal portions are seen. There occur, however, two-ovuled (then stalked) divided carpels; and this fact proves that the cup-shaped swelling at the base of the *Ginkgo* ovule is only an annular fold of the carpel, corresponding to that of the *Cycas* ovule⁽¹⁾. Thus he considers the female flower as a real single flower. Further he considers the entire brachyblast of *Ginkgo* as an inflorescence, which is not closed to form a cone but open and diaphytic, and in which the subtending leaf of a flower is a normal foliage leaf (or a scaly leaf). He suggests also that the flowers of both sexes in "*Proconiferæ*" were much more alike (the female nearly like the many-ovuled, decussate, pleocarpellary variation of *Ginkgo*) and similarly

⁽¹⁾ "Referat," Bot. Zeitung, Jahrgang 49 (1891), p. 719.

situated, that is, terminal to "brachyblasts" which originally produced flowers only; and that the carpels and stamens of the flowers of "*Archigymnospermæ*," from which the present *Gymnospermæ* have been derived had marginal ovules (as *Cycas*) and pollen-sacs or small groups of pollen-sacs associated in numbers of 2-3⁽¹⁾.

My own observations.:—Numerous instances of progressive metamorphoses of different parts of floral organs are on record, but no instances of staminody and pistillody (carpellody, if I may use the term) of foliage leaves are found in chief literature of vegetable teratology. These unusual cases of anamorphosis, showing various steps of progressive metamorphoses are occasionally found in *Ginkgo*.

My observations were made chiefly on two old female *Ginkgo* trees in Shimoyama village, Minami-koma county in the province of Kai, on the west bank of the river Fuji, and a male *Ginkgo* tree in Kami-yagisawa village, Nishi-yashiro county in the province of Kai, on the east bank of the river. These two female trees⁽²⁾ produce ovules, and the male tree⁽³⁾ pollen-sacs, in the marginal portion of foliage leaves of the "Kurztriebe" as well as in their normal positions of the flower. Such abnormal formations of floral organs are found abundantly in these trees; but as a rule neither in every "Kurztrieb" of a branch, nor in every leaf of a "Kurztrieb." But often some of the leaves of a "Kurztrieb" produce such abnormal formations; and all the rest only show indications of such.

The number of ovules or pollen-sacs formed upon a single leaf varies from one to thirteen or more, and the formation of such ovules or pollen-sacs always takes place partly in expense of the tissue of the leaf, the margin of the latter being notched at the point of the formation. So in many cases the lamina of the leaf is almost entirely transformed into a group of ovules or pollen-sacs. The form of ovules or pollen-sacs is then very irregular and deformed, but when they are few in number and not crowded, it is generally the same with that of normal ones. The ovules and fruits formed upon the leaf are always smaller than normal

(1) Author's "Referat," Engl. J., XII, 1890, Lit.-Ber., p. 66-76.

(2) One of the two trees grows in the yard of the Buddhist temple Jōtakuji (上澤寺), and was found in July, 1891 by Mr. M. Shirai. The other tree grows in the yard of Honkokuji (本國寺), and was found by myself in Oct., 1891, during my journey to Shimoyama, intended for the closer observation of the female tree of Jōtakuji, with the permission of the discoverer.

(3) The male tree was found on my second visit to Kai in April, 1892.

ones and the micropyle is rather pointed, and also the pollen-sacs formed upon the leaf are in majority of cases smaller than the normal ones.

The ovule has often a longitudinal striation along the plane of the lamina of the leaf. It is more marked in the fruit (fig. 2, g.), and corresponds to the prominent edges of the stony part of the seed, which is sharply pointed and smaller than a normal one. The ovule is partially enclosed at the base in a cup-shaped swelling just as in the normal ones, and this swelling gradually passes into the lamina of the leaf.

Often elongated outgrowth of the tissue is formed, instead of ovules or pollen-sacs of any definite form, mostly in the margin of the leaf for some length along the course of the veins of the leaf (fig. 1 and 4, e.).

Pollen-sacs developed at the margin of the leaf is neither arranged in any definite numbers, nor in any definite manner so as to form sori. As a rule no special terminal scale ("Endschuppe") is developed; but sometimes when an entire leaf is transformed into a stamen, the reduced lamina of the leaf assumes the form and position of the terminal scale. Pollen grains with proper number of cells are developed in the anther.

The petioles of leaves bearing ovules are of normal size, but those bearing pollen-sacs are often much reduced in length and thickness.

Besides the staminody and carpellody of foliage leaves, various instances of multiplications and proliferations of floral organs are found in these same trees.

The flowers with 3-13 or more ovules, each of which is provided with its own stalklet are produced in abundance. The ovules are at first mostly alternate, but their position is usually disturbed during their subsequent growth.

Fig. 3 illustrates an interesting case. The flower-stalk is larger than that of a normal flower both in length and thickness. The ovules, each of which is raised on its own stalklet, are developed alternately along the common flower-stalk (the floral axis), but the uppermost(?) one has grown over the others. Moreover the flower-stalk (the floral axis) is terminated with a scaly bud, which decidedly disproves the foliar nature of the flower-stalk, though it was considered as a leaf-stalk by Van Tieghem.

Not only the flowers with a number of ovules provided with their own long stalklets are met with, but also flowers with a number of sessile ovules and several intermediate forms between such an abnormal flower and a normal two-ovuled flower.

In "Kurzztriebe" of weaker development, however, flowers with a single ovule with a rather slender stalk are often met with; and the cross sections of such a stalk sometimes show one or two fibrovascular bundles similarly situated as those of the petiole of the foliage leaf, while sections of the stalk of a normal two-ovuled flower show generally four bundles so arranged as to have two planes of symmetry. A flower-stalk with one or two fibrovascular bundles is therefore to be considered as equivalent to a leaf-stalk, the petiole of the carpellary leaf.

In the cross sections of the stalk of a many-ovuled flower we find, as a rule, as many fibrovascular bundles as the ovules; and each bundle divides into two in its course, previous to its entrance to the stalklet of each ovule; so that in a cross section of the stalklet we find a pair of fibrovascular bundles similarly situated as those in the petiole of the foliage leaf.

Although a great number of specimens have been studied, no foliar structure like a bract has been found subtending the stalked ovule.

These facts together with the formation of ovules upon the foliage leaves, present a strong evidence of the foliar nature of the ovule, in accordance with the view of VAN TIEGHEM, EICHLER, ČELAKOVSKÝ, &c., and contrary to the view of STRASBURGER and others, who consider it as an organ of axial nature.

In the male flowers, stamens with three anthers are often met with. I have also found a brachyblast consisting of scaly leaves around the base and a male inflorescence, in which there is a single foliage leaf of weaker development.

As to the cause of the carpellody and staminody of the foliage leaves, I am not yet ready to express any definite opinion; but the multiplication and proliferation of the floral organs are mostly associated with hypertrophy.

Conclusion :—1. The prominent edges of the stony part of the seed correspond to the margin of the carpellary leaf; and that is why there are neither fibrovascular bundles, nor even any special cell rows found in them.

2. The ovule is an organ of foliar nature, and the cup-shaped swelling at its base is the reduced portion of the lamina of the carpellary leaf.

3. The anther is an organ of foliar nature, and its knob-like terminal scale ("Endschuppe") is the reduced portion of the lamina of the staminal leaf.

4. The ovules and the anthers of *Ginkgo* are both marginal formations of sporophylls, though the anthers of *Coniferae* in general have hitherto been often considered as organs developed on the under surface of staminal leaves.

5. The normal seed-stalk is the floral axis, whose apical bud is usually suppressed, and which bears only two rudimentary carpels.

6. The elongated stalklet of the ovule of *Ginkgo* occasionally developed is not simple outgrowth, as has been considered by some authors, but is the petiole of the carpellary leaf developed alternately along the floral axis.

7. The normal female flower is not an inflorescence as has been considered by STRASBURGER and others, but a real single flower as considered by EICHLER, ČELAKOVSKÝ, and others.

8. The disputed point in the homology of male and female flowers of *Coniferae* is thus clearly established as far as *Ginkgo* is concerned, as is seen when we compare a normal male flower and a female flower with a number of stalked ovules.

Remarks on the phylogeny of Ginkgo:—The view that among *Coniferae* *Ginkgo* comes nearest to *Cycadaceae* has hitherto been often held on account of its lobed dichotomously veined leaf and drupaceous fruit. We may here briefly enumerate the points of resemblance between *Ginkgo* and *Cycadaceae*, and especially *Ginkgo* and *Cycas*.

(a) The formation of ovules upon the foliage leaves of *Ginkgo* reminds us of the carpellary leaves of *Cycas*, and the ovules are on both genera marginal formations of the sporophyll.

(b) Drupaceous fruits of *Ginkgo* and *Cycadaceae* much resemble each other.

(c) The neck of archegonia consists in both *Ginkgo* and *Cycadaceae* of two cells.

(d) The formation of the canal cell was formerly believed not to take place in *Cycadaceae*, while it was well known in *Ginkgo*, and indeed in *Coniferae* in general; but it has been recently proved to take place in *Cycas revoluta*⁽¹⁾.

(1) S. Ikeno. Vorläufige Mittheilung über die Canalzellbildung bei *Cycas revoluta*. Bot. Centralblatt. Bd. LXVII. No. 7, p. 193 (1896).

S. Ikeno. Note préliminaire sur la Formation de la Cellule de Canal Chez le *Cycas revoluta* (With pl. V.). The Bot. Mag. Tōkyō, Vol. X, No. 115, Part II p. 63 (1896).

(e) Long after WILHELM HOFMEISTER wrote "in dessen [Pollenschlauch d. Coniferen] Innerem *vielleicht* Samenfäden sich bilden,"⁽¹⁾ spermatozoids have been found in *Ginkgo biloba*⁽²⁾ and *Cycas revoluta*⁽³⁾ for the first time in 1896; and the behavior of their pollen in regard to the process of fertilization has been found to be similar⁽⁴⁾.

(f) The "kurztrieb" of *Ginkgo* is exactly similar in all essential morphological points to the stem of *Cycadaceæ*; they are both usually unbranched, but sometimes copiously branched.

Thus we see that *Ginkgo* and *Cycas* is so near to each other that *Ginkgo* is more closely related to *Cycas* than to most other genera of *Coniferæ*; but at the same time they deviate from each other in the following respects:—(a) In *Cycas* pollen-sacs are borne on the under surface of the staminal leaf, while in *Ginkgo* they are borne on the margin of the sporophyll; (b) *Ginkgo* has "Langtriebe" and "Kurztriebe," while *Cycas* has "Kurztriebe" only; and their leaves are greatly different in form, habit, and structure; (c) the embryo of *Ginkgo* has no suspensor, while that of *Cycas* has one.

The formation of sporangia on the margin of leaves, the lobed dichotomously-veined leaves, and the formation of spermatozoids are the most remarkable points which *Ginkgo* and some ferns have in common.

Such a plant as *Ginkgo* might have been derived from some kind of Ferns, but not from *Lycopodiaceæ*, to which many other genera of *Coniferæ* are closely related. In fact, *Coniferæ* may be a heterogeneous group; and *Ginkgo* may be properly established as a distinct family among *Gymnospermæ*, that stands between *Cycadaceæ* and *Coniferæ* as one of the four main branches of *Gymnospermæ*, but not as a connecting link between *Cycadaceæ* and *Coniferæ*.

(Concluded.)

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Tōkyō, Dec. 17th, 1896.

(1) Vergl. Untersuchungen u. d. Samenbildung d. Coniferen. p. 140 (1851).

(2), (4). S. Hirase. On the Spermatozoid of *Ginkgo biloba* (Japanese). The Bot. Mag. Tōkyō, Vol. X., No. 116, Part. I, p. 325.

(3), (4). S. Ikeno. On the Spermatozoid of *Cycas revoluta* (Japanese). The Bot. Mag. Tōkyō, Vol. X., No. 117, Part I, p. 367.

EXPLANATION OF PLATE I.

Fig. 1. A female "kurztrieb." *a* apical scaly bud; *b* normal female flower; *c* leaf bearing irregular outgrowths of tissue; *d* leaf bearing ovules; *e* irregular outgrowth of tissue; *f* cup-shaped swelling at the base of the ovule; *g* longitudinal striation of the pulpy portion of the seed.

Fig. 2. A foliage leaf bearing a ripe fruit. *g* longitudinal striation of the pulpy portion of the seed.

Fig. 3. A female flower with an apical bud and a number of stalked ovules. *f* cup-shaped swelling at the base of the ovule.

Fig. 4. A branched "Kurztrieb," in which the main axis *a* and the branch *c* are dead, and the branch *b* only is alive. *d* normal male flower; *e* elongated irregular outgrowth of tissue; *g* leaf bearing anthers; *h* normal foliage leaf.