IX. *On the Fruit of Melocanna bambusoides, Trin., an Endospermless, Viviparous Genus of Bambuseæ. By Dr. OTTO STAPF, F.L.S.*

(Plates 45-47.)

Read 20th March, 1902.

“Die ganze Lebensweise der Gewächse beruht auf Anpassungsverhältnissen, und die morphologische Ausbildung ihrer Organe wird erst unter dem Gesichtspunkte der Anpassung verständlich.”—WIESNER, *Biologie der Pflanzen*, p. 9.

AMONG the Bambuseæ there are three genera the fruits of which are described as large or very large caryopses, either with a coriaceous pericarp and a fleshy seed, or with a very thick, fleshy pericarp. Some of these fruits have been figured, and however meagre the figures may be in details, they suggest at once an unusual deviation from the typical structure of the grass fruit. The genera are *Melocanna*, *Melocalamus*, and *Ochlandra*, and I will summarize briefly the little we know about the structure of their fruits before dealing with the special subject of this paper.

Melocanna is supposed to comprise two species, like *Melocalamus* natives of Eastern Bengal and Burma. I shall have to say more about the number of species later on, and will confine my remarks in this place to the fruit of what is generally known as *M. bambusoides*, Trin. This fruit was first described and figured by Roxburgh in his ‘*Plantæ Coromandelianæ*,’ iii. pp. 37, 38, tab. 243, in 1819, as the fruit of a new species of *Bambusa*, viz. *B. baccifera*. According to the diagnosis, it is “a very large, pendulous, pyramidal, one-seeded berry,” and according to the description, “a very large, hard, fleshy, conical, smooth, taper, curved, pointed fruit with a single large oval seed.” The figure of the fruit in the plate quoted above is very well done, but the longitudinal section, which is also shown, does not pass through the axis of the embryo, and gives therefore an inadequate idea of the structure of the seed, which was no doubt the reason why it has so long remained unknown. Trinius recognizing a new genus in Roxburgh’s *Bambusa baccifera*, proposed (in Sprengel, *Neue Entdeck.* ii. (1821) p. 43), two years after the publication of the ‘*Plantæ Coromandelianæ*,’ the name *Melocanna* for it, and *M. bambusoides* for the species. Not having seen specimens, he ventured to explain the structure of the fruit by assuming that the fleshy case containing the seed was formed by the thickening and fusion of the lodicules, “ungefähr wie sich die Blumenschuppen von *Taxus*, *Juniperus* und ähnlichen zur Beere bilden.” This explanation of the very singular fruit was suggested to Trinius, as he himself says, by the three swellings at the base of the fruit shown in Roxburgh’s figure. All later references to *Melocanna* up to the publication of Munro’s “*Monograph of the Bambuseæ*” (in *Trans. Linn. Soc.* xxvi., 1868) are based on Roxburgh’s description, adding no fresh information on the subject. Nor did Munro himself see specimens of the fruit of *Melocanna*, but he quotes a few lines from a

communication by W. Theobald, of the Geological Survey of India, who had observed the plant in Arakan, and writes "that the true seed inside the fleshy pericarp, about the size and shape of a small betel nut, is very pleasant eating, and not at all austere, though without much flavour. The natives declare the whole fruit is edible after baking"*. Munro, like Trinius, could not resist the temptation to speculate on the morphology of the fruit he knew only from a picture and a description, but which must have appeared to him very anomalous indeed. In speaking of the "berry-bearing Bamboos" (among which he counted, by the way, also genera which have no baccate fruit) he says, Trans. Linn. Soc. xxvi. (1868) pp. 4-5:—"They are all extremely interesting from their peculiar fruit. The pistil generally appears to be contained in an envelope somewhat analogous to the sac, or utricle, or perigynium, which contains the seed of *Carex*. In the young state this is so closely attached to the style that it is almost impossible to separate it; in advancing to maturity it increases in various ways. In *Melocanna bambusoides* it becomes very fleshy, and the fruit attains the size of a largish pear." Munro's hypothesis, which is practically a repetition and extension of Trinius's explanation, was disposed of by S. Kurz, who had had an opportunity of studying the fruit of the "berry-bearing Bamboos" more closely. He writes in the 'Indian Forester,' i. p. 266, referring to Munro's theory, "But this view, on a more careful examination, has turned out to be unfounded, for this supposed perigynium is virtually nothing else but the indurated outer wall of the ovary (pericarp), while the inner stratum of looser cells becomes detached from the outer wall and remains as a spongy mass round the true seed." Speaking in another place (*l. c.*) especially of *Melocanna bambusoides*, or, as he calls it, *Melocanna baccifera*, he says:—"Still more interesting are the fleshy fruits of *Melocanna baccifera*, which attain 4 inches by 3, and besides terminate into a fleshy beak about 2 inches long, so that the whole length amounts to 5 inches! Here the seed is comparatively small, while it is the fleshy pericarp which makes the fruit so bulky. These also germinate while still growing on the plant, and Mr. W. L. F. Robinson of Rungpore thus describes the germination: 'A good watch was kept on those fruits on the trees, and the result is this, as they get ripe, out of the big end, by which they hang from the tree, springs a young bamboo leaf and also a bunch of roots; when the young shoot is some 6 in. long, the whole thing drops off the tree, and apparently plants itself in the ground by the roots. It seems a queer thing that the bamboo should reproduce itself on the tree without going to the earth first.'" Unfortunately, Kurz stopped short of examining the seed, and it does not seem to have struck him at all, that the structure of the seed itself was at least as singular as that of the pericarp. Gamble has reproduced ("Indian Bambuseæ," in Ann. Bot. Gard. Calcutta, vii. tab. 105. fig. 9) a crude figure of a fruit in longitudinal section from a drawing by Kurz, preserved in the Calcutta collection. It is evidently a tangential section, passing through the seed near its periphery, and therefore showing a central cavity

* Theobald published later on and independently some further observations on this bamboo in the second edition of Mason's 'Burmah,' ii. p. 101 (1883). Here he says of "*Melocanna (Bambusa) baccifera*, Roxburgh": "An arboreal bamboo, 50 to 70 feet high. Leaves quite glabrous. Caryopsis ovate, the size of a guava or small pear. This is, I think, the Bamboo I found covering large areas in the Arakan Range. When I observed it, the fruit was formed and pretty closely resembled a green guava, and internally was harder than a potato."

with a mere fragment of the scutellum, of course without any trace of differentiation, a figure which if compared with the ordinary grass fruit is unintelligible and necessarily misleading. No botanist since Kurz seems to have examined the *Melocanna* fruit, and even Bentham and Gamble had to fall back on Kurz's description, imperfect as it is.

Melocalamus is a monotypic genus. The only species, *M. compactiflorus*, Benth., is found in Eastern Bengal and Burma. Although common enough at certain altitudes, it was until lately collected only once in fruit, namely by S. Kurz, who described it in Journ. As. Soc. Beng. xlii. (1873) pt. II. p. 252, and in his 'Forest Flora of Burmah,' ii. p. 567, and figured it in the 'Indian Forester,' i. (1875) p. 266, tab. ii. fig. 13. He says of the fruit in the 'Indian Forester,' l. c.: "*Pseudostachyum compactiflorum* (Kurz's synonym for *Melocalamus compactiflorus*) has irregularly globose fruits, the size of a small woodapple, which germinate already while still attached to the mother plant. This has the largest seed of all bamboos, the pericarp being thin and coriaceous." The description in the 'Forest Flora of Burmah' amounts to the same; but he adds that the seed is "mealy-fleshy" or "fleshy." The figure quoted above represents two fruits still attached to the branch, and corresponding to the description, no analyses being given. One of the fruits of Kurz's plate has been reproduced by Gamble, 'Indian Bambuseæ,' tab. 84. This is all that is on record with regard to the fruit of *Melocalamus*.

Ochlandra, the last of the three genera mentioned, is represented by several species in the south-west of the Deccan Peninsula, one in Ceylon, and one in the Malay Peninsula. It was already known to Van Rheedee, who described and figured a species of it in his 'Hortus Malabaricus,' v. p. 119, tab. 60 (1685), as *Beesha*, adding that the fruit was unknown. Curiously enough, there are, however, two crude figures in the lower left-hand corner of his plate which undoubtedly represent an entire fruit and another in cross-section. The first to describe the genus technically was Thwaites, in his 'Enumeratio Plantarum Zeylanicæ,' p. 376 (1864). He called it *Ochlandra*, and says of the fruit: "Caryopsis maiuscula ovoidea, stylo persistente indurato acuminata, paleis squamisque spiculæ tecta." Munro, in his "Monograph of the Bambuseæ," had nothing to add to this extremely meagre description. Beddome also hardly advanced our knowledge when describing the fruits of three distinct species of *Beesha* (Munro's name for *Ochlandra*) in his 'Flora Sylvatica,' vol. ii. p. cccxxiv, except in so far as we learn from him that the pericarp of *O. travancorica* is fleshy; but he gave an excellent habit figure of an *Ochlandra* fruit, the largest and the most peculiar in the genus (l. c. tab. 324. fig. 11). It is the fruit of *O. travancorica*, and he describes it thus: "Fruit oblong or ovate, fleshy, embraced by the palea, about $1\frac{1}{2}$ in. in diam. and $2\frac{1}{2}$ in. long, with a hard beak about 2 in. long." To this figure Gamble added (l. c. tabb. 108 & 109) equally faithful habit figures of the fruits of *O. Rheedii* var. *sivagiriana*, Gamble, and *O. stridula*, Thw., but no dissections.

This concludes the summary of our knowledge of these very singular grass fruits. It is very fragmentary and entirely confined to some of the most conspicuous external characters. In these circumstances I consider it my particularly good fortune that I was, through the kindness of Sir Dietrich Brandis, enabled to examine a number of excellently preserved fruits of *Melocanna*. The first set of fruits was forwarded to him

by Mr. A. E. Wild, late Conservator of Forests, Bengal, in the autumn of 1901 *, and it was on them that this paper was based in its original form as read before the Society on March 20, 1902. Before going to press, however, I received through Sir Dietrich Brandis another batch of *Melocanna* fruits from the same source, stated to have been collected in the Chittagong District, and later on a third set, communicated by Mr. N. K. Mukherji, Extra-Assistant Conservator of Assam, and consisting of unripe fruits and flowers gathered in the Garo Hills. As the fruits with which I had been working originally were almost without exception perfectly mature or even germinating, I was frequently obliged to form my ideas concerning the morphologic value of parts of the fruit and the general development by inference from the mature state. Hence more than one point necessarily remained doubtful. The new material, particularly that from the Garo Hills, offered an opportunity for extending my researches to the earlier stages of development and revising my conclusions. I thought it only right to avail myself of it at the risk of considerably delaying the publication, as other work had meanwhile claimed my time. These efforts of broadening and deepening the basis of my investigations resulted in the confirmation—in the essential points—of the conclusions laid down in the short abstract of my paper contained in the Report of the Society's meeting of March 20, 1902 †, in the explanation of certain particulars in the structure of the *Melocanna* fruits which were unknown or imperfectly understood before, and in a more complete account of their development based on the immediate observation of the successive stages. There also was some uncertainty as to the specific identity of the plants figured by Roxburgh in his 'Plantæ Coromandelianæ,' tab. 243, as *Bambusa baccifera*, and by Gamble in his "Indian Bambuseæ" (in Ann. Bot. Gard. Calc. vii. tab. 105) as *Melocanna bambusoides*, and accordingly also with respect to the correct determination of the fruits I had to deal with. I discussed therefore this question in full, so that it might be studied in the field. The new material, however, dispelled my doubts, which, as it now appears, had been caused by the very remarkable heteromorphy of the inflorescences of *Melocanna bambusoides*, a condition hitherto unknown. Hence I cancelled the paragraph dealing with the suspected identity of the plant depicted by Roxburgh and Gamble respectively, reserving a full description of the inflorescences, as being beyond the limits of this paper, for another occasion.

My original intention was to include the fruits of *Melocalamus* and *Ochlandra* in the scope of my investigations; but considering the scantiness of the material pertaining to those genera to which I then had access, I preferred to confine myself to *Melocanna*. I hope, however, before long to have an opportunity of publishing an account of the structure of the fruits of *Melocalamus* and *Ochlandra*, of which I have since received good material through the courtesy of Sir Dietrich Brandis and Mr. T. F. Bourdillon, Conservator of Forests, Travancore.

I am also under great obligation to Mr. J. S. Gamble for the loan of his herbarium

* Kew had received a few equally good specimens from the same source in 1900, but as they were reserved for exhibition purposes in the Museum, I did not include them in my investigations beyond an examination of the external features.

† See 'Nature,' vol. lxx. p. 548.

specimens of *Melocanna*, to my friend Prof. Hans Molisch of Prague and to Mr. G. F. Herbert Smith of the Mineralogical Department of the British Museum for the examination of certain crystals found in the fruits, and finally to Mr. L. A. Boodle for assistance in several points which I shall have an opportunity of mentioning in this paper.

I. THE SPECIES OF MELOCANNA AND THEIR DISTRIBUTION.

The genus *Melocanna* is confined to India. Two species are described and figured by Gamble in his 'Indian Bambuseæ' as belonging to it, viz. *M. bambusoides*, Trin., and *M. humilis*, Kurz.

Melocanna bambusoides ranges from the Kamrup District on the north side of the Khasia Hills to the Attaran District in Tenasserim, inhabiting a belt which lies entirely within the zone of heavy rainfall (over 2000 mm. per annum) *, but with a distinct dry and rainy season, the latter covering approximately the months from May to October. The "locus classicus" of Roxburgh's *Bambusa baccifera*, the basis of the species, is somewhere in the "Chittagong Mountains," whence a Mr. Richard Pierard sent "growing plants, seeds, and well-preserved specimens" to Roxburgh, as it seems, in 1801; this, at least, is the date given in Roxburgh's 'Hortus Bengalensis,' p. 25. The locality is not further specified, but as Pierard says, in his note to Roxburgh, that the bamboo "grows in dry places, chiefly on the sides of hills, where the upper stratum of the soil is sandy," I infer that he meant the lower outer ranges, which in part consist of sandstone.

The second species, *M. humilis*, was described by S. Kurz from barren specimens and must not be confused with *M. humilis*, Rupr., which is an Amboina plant, figured by Rumphius and evidently not a *Melocanna* at all. Kurz indicates his *M. humilis* from the mixed forests of Arakan and from the Pazwoondoung Valley, Pegu. It may be a *Melocanna*, but so very little is known that I may well pass it over.

Finally, I wish to point to what seems to be a third species of *Melocanna*. My attention was called to it by a specimen consisting of a leafy twig and the end of a very curious stolon. It was collected by C. B. Clarke at Eerung in Muneypoor and numbered 42188 a. The leaves are very like those of *Melocanna bambusoides*, but the stem is described on the label as thorny. Mr. C. B. Clarke has kindly supplied me with a note on this bamboo, which will, I hope, lead to its rediscovery and thorough examination. He writes:—"When I was at Dacca in 1868, an officer, who had been on survey in the East Cachar Hills, showed me a large seed of *Melocanna*, as big as that depicted by Roxburgh. He told me that this bamboo occupied 6000 square miles of country; that it had fruited the last season; that he stopped his survey six weeks earlier owing to the fall of seeds breaking theodolites and plane tables; that the whole of the old plants had died after seeding; that the whole country could be seen covered with seedlings. Subsequently, in 1885, I marched from Muneypoor to Cachar, across the country reported to me by the surveyor in 1868, and was for several days in a uniform, almost pure, jungle of *Melocanna*. The powerful stolons formed a horizontal mass, and I with difficulty dug up the end of one, now in the herbarium at Kew. The stems of this

* Bartholomew, Phys. Atl. vol. iii. pl. 25.

bamboo, erect, solitary, about 1-2 yards apart, occupied the ground almost exclusively, with no jungle under them, and shut out all view. The stems were, by recollection, $1\frac{1}{2}$ in. in diam., about 30 feet high, leafy at the top, yellow, with spines at every node. The specimen now in Kew has no piece of the stem, but it has the note, made on the day of collection, mentioning the thorns on the stems. Though the stems stood a yard or two apart, the jungle was most tedious to penetrate, unless you allowed the clothes to be torn from your back and the flesh from your bones. I noted the plant at the time as a species different from the *Melocanna bambusoides* of Herb. Kew. (in which I was possibly right, as I then knew the latter by sight). In the jungle covered by this thorny *Melocanna*, which came into fruit all simultaneously after growing 40 years or so vegetatively, it would be difficult to place a plane table so that the seeds should not fall on it. It is a most dreary country to march in; when you reach the top of a hill, there is no look out."

II. HABIT OF MELOCANNA BAMBUROIDES.

Melocanna bambusoides is described by Gamble ('Indian Bambuseæ,' p. 118) as "an evergreen, arboreous bamboo, with single distant culms arising from the ramifications of an underground rhizome. Culms tall . . . unbranched till near the top, 50-70 feet high, 1.5 to 3 in. in diameter Owing to its habit of sending out long underground rhizomes which give out culms at intervals, it spreads very rapidly and is extremely difficult to get rid of." Like many other bamboos it loses its foliage when it begins to flower (Roxburgh, Plant. Coromand. iii. p. 38). When finally deprived of all its leaves the top with its numerous inflorescences borne on the gigantic culm, as on a peduncle, presents a singular appearance, which suggested to Kurz "an ample, after the fall of the leaves, radical panicle" (Forest Flora of Burmah, ii. p. 569). Kurz went too far in thus reducing the whole of the flowering culm to a single panicle, and it appears to me certainly more expedient to confine the term "inflorescence" to the dense aggregations of spikelets which terminate the flowering branches above a succession of perfect leaves (with early deciduous blades) and to their lateral and basal homologues, whether they are preceded by perfect leaves or not. These flowering branches are gathered in fascicles springing from the nodes of the culm and its branches in the region of the top of the bamboo. They vary not only in size and number, but also very considerably in structure and habit, as a comparison of Roxburgh's and Gamble's plates will show, so much so, indeed, that the figures depicted there suggest distinct species. In reality, they represent only the two types of inflorescence of which the fascicles are made up, either so as to contain only inflorescences of one kind or a combination of both. One set of inflorescences may be described as androdynamous, namely predominantly or exclusively male, the other as gynodynamous, namely predominantly or exclusively female, hermaphrodite flowers occurring occasionally in either. Intermediate forms exist, but they are very rare. There are consequently three conditions possible in the grouping of the inflorescences: (*a*) uniformly androdynamous fascicles, (*b*) uniformly gynodynamous fascicles, and (*c*) mixed fascicles. How they are distributed over the top of the bamboo, or whether there is ever an approach to dicecism, I cannot say. The fruits are, of course,

produced mainly on the gynodynamous inflorescences, slender spikes from a few to 30 cm. long. Where they occur in androdynamous inflorescences which represent much decompound panicles, they are always few and usually terminal or subterminal on the branches or branchlets bearing them. They spring from sessile, 1-2-flowered spikelets, the bracts (glumes, valves, pales) of which persist after flowering in an unchanged though withered condition. Nor does the axis of the spikelet which acts as a very short fruit-stalk outwardly suffer any transformation, the necessary strengthening being provided for, here as well as in the axes of the inflorescences, by internal changes resulting in the development of sufficient mechanical tissue. Thus the fruits hang, by means of very short and slender stalks of great tensile strength, from the flexible and wiry axes of the inflorescences.

III. DURATION OF LIFE ("FLOWERING PERIOD").

Melocanna bambusoides is, like many other bamboos, so far as we know, monocarpic. It is a gregarious plant forming extensive forests, and flowers and fruits simultaneously over large tracts at long periods, each period corresponding to one generation. Kurz (in 'Ind. Forester,' i. p. 257) says it flowers and fruits in Arakan every 30 to 35 years. The dates of flowering and fruiting which I have been able to ascertain are: 1801 for Chittagong (Pierard in Roxburgh, Hort. Beng. p. 25), 1849 for Tenasserim (Falconer in Hb. Kew.) *, 1863-1866 for the Botanic Garden, Calcutta (Gamble, Ind. Bamb. p. 120), 1864-1865 for Arakan (Kurz, *l. c.* p. 258; this is evidently the fruiting to which Theobald refers in Mason, 'Burmah,' 2nd ed. ii. p. 101), 1889 for the Garo Hills (specimen in Gamble's herbarium), 1892 for "Assam" (Gamble, *l. c.*), and 1900 to 1902 for the Garo Hills, Cachar, and Chittagong (specimens received by Sir Dietrich Brandis). It is clear from these dates that we cannot speak of a *general* "flowering period" of 30-35 years in the case of *Melocanna bambusoides*, although it may be quite true that the normal duration of life of this monocarpic bamboo is 30-35 years. We can hardly assume *a priori* that the flowering should take place simultaneously (or, what is about the same, that all the individuals of this species should be of the same age) over the whole area with its varied conditions of soil and climate, and in fact we know that this is not the case with other gregariously flowering bamboos (see Brandis in 'Indian Forester,' xxv. 1899, p. 10). The dates for the Garo Hills—to which that for "Assam" may be added, as by "Assam" no doubt the south-western corner of the Kamrup District is meant—are particularly instructive, as we learn from them that flowering took place at least three times during a period of about 12 years within a limited area. There is, however, no evidence to show what portions of the area were affected each time, or how far the flowering was general in the affected portions. More numerous observations, extending at the same time over the whole area, are necessary, in this as in the case of other "periodically" flowering bamboos, before we can understand this remarkable "periodicity."

* A flowering specimen, collected by Falconer in "Moulmein," was formerly in the Kew Collections. According to a note it was sorted out because it was identical with another flowering specimen cut by Kurz in the Botanic Garden, Calcutta. Falconer was in Moulmein and the Attaran District early in 1849, and I assume the specimen was then collected, although he does not mention it especially in his "Report on the Tenasserim Teak Forests."

IV. GENERAL FEATURES OF THE MATURE FRUIT.

The mature fruits are ovoid to globose (Pl. 45. figs. 1-7), passing above into a short or even obscure, or long and then more or less curved beak. They vary much in size. Whilst the smallest which I examined measured 4 by 3.5 cm., the corresponding figures of the largest were 12 by 5.5 cm. The weight also varies accordingly from 47 grams to 180 grams. The fruits are glabrous, smooth or somewhat wrinkled, green, fleshy, but hard and tough. Nearly always 3, or sometimes 5, faint, obtuse, longitudinal ribs may be observed, one of which descends towards the palea and may therefore be termed ventral, whilst the other two are lateral. Opposite to the ventral ridge a shallow and often very obscure groove extends towards the base, ending close to the point of attachment of the fruit. Here a slight swelling (figs. 1, 3, *et.*), covered by the valve or floral glume, indicates the spot where the embryo breaks through the pericarp in the course of germination. This embryo spot or embryotegium is, however, by no means so distinctly defined as in typical grass fruits, nor is there any trace of a hilum discernible.

A section in the median plane (Pl. 45. fig. 3) of the fruit reveals the following main features of the internal structure:—

1. A hard, fleshy, thick *pericarp* (Pl. 45. figs. 3, 5, 7, *p.*), of a very homogeneous substance, enclosing an oblong cavity, extending from the embryotegium to about $\frac{2}{3}$ or $\frac{3}{4}$ of the length of the fruit (exclusive of the beak), and of approximately central position, its greatest diameter being equal to about $\frac{1}{3}$ of the diameter of the fruit.

2. A delicate layer (Pl. 45. figs. 3, 5, 7, *d.*), lining the cavity and almost indistinguishable to the naked eye, but discernible under the lens as a fine membrane or in cross-section as a fine line of a substance different from that of the pericarp. This layer I call the *diaphragm*.

3. The *embryo*, consisting of the embryo proper (Pl. 45. fig. 3, *pl.* & *r.*), situated close to the embryotegium, and a many times larger fleshy body (figs. 3, 5, 7, *sc.*), the equivalent of the scutellum of the typical grass seed, filling up more or less completely the cavity.

This very general description discloses already—apart from the great size of the fruit—*several very remarkable characters which do not occur in the typical grass fruit, viz. the powerful development of the pericarp, the absence of endosperm, the corresponding enlargement of the scutellum, and the interpolation of a diaphragm film between pericarp and scutellum, to which may be added the vivipary, mentioned in the introductory part.* This deviation from the normal structure of the grass fruit is more or less repeated in the fruit of *Melocalamus* and in a modified form in that of *Ochlandra*, although the latter is not, so far as we know, viviparous. Otherwise it seems to be without a parallel in the large order of Gramineæ, which exhibits so great a uniformity in the structure of the fruit. To understand these very singular modifications and their mutual correlation, it is necessary to examine the development of the fruit from the ovary stage and its internal morphology in the mature condition. This will be done in the next chapters.

V. THE DEVELOPMENT OF THE FRUIT.

When I read this paper in its original form before the Society, I remarked that I had not had an opportunity of examining young fruits and knew therefore nothing from direct observation of their stages of development prior to almost complete maturity. The material since received, although not so good and complete as might be wished, has filled the gaps sufficiently to enable me to give a more complete account of the development and structure of this remarkable bamboo fruit; but the early stages of the ovule still require close examination.

The pistil (Pl. 45. figs. 8–10) of the hermaphrodite or female flowers is bottle-shaped, very slender and long-exserted from the spikelet, freely exposing three more or less unequal curved, feathery or, as Roxburgh describes them, woolly stigmas. The ovary is not distinctly separated from the style, but passes imperceptibly into it; but if we estimate its length by that of the ovarial cavity, we find it to be several times shorter than the style. The pistil is more or less distinctly 5-grooved from the base upwards to or beyond the middle, the ridges separating the grooves being so placed, that one is ventral (fig. 2, 15, *vr.*), *i. e.* facing the palea, whilst the others are lateral, the ventral ridge being generally the least prominent of them. The body of the pistil consists mainly of small-celled parenchyma and is traversed longitudinally by 15 or more vascular (fig. 15) strands, the position of which is marked in cross-sections of the fruit by the presence of usually solitary tracheids. Their disposition is, however, apparently quite independent of the orientation of the ovule.

The ovule (Pl. 45. figs. 12–15) is in the position usual in Gramineæ. In the mature pistil it is 1–1.5 mm. long and very slender, and on the whole small in comparison with the ovary, its diameter being only $\frac{1}{3}$ – $\frac{1}{4}$ of that of the ovary. It is attached to the pericarp with a very broad back, with the exception of the short, free, somewhat oblique and basiscope apex, and fills the ovarial cavity so completely that the latter appears in cross-sections made from spirit-material as a very slender crescent. The ovule-wall thins out towards the front, but there is no differentiation into integuments and nucellus, and accordingly also no micropyle. *The ovules are therefore actually naked.* Still there is this to be observed, the cells of the two outermost layers of the ovary-wall (fig. 14) are slightly larger than those of the following inner tissue, and they stain with Schultz's solution yellow, whilst the cell-walls of the remainder of the ovule stain blue, a reaction which indicates the first stage in the disorganisation which the peripheral portion of the ovule-wall undergoes, as I shall have to show presently. The small-celled tissue which surrounds the very large embryo-sac (Pl. 45. figs. 13–15, *es.*) in the front half of the ovule continues also over the back, where it passes gradually into cells of greater diameter, such as build up the bulk of the pistil. How the pollen-tubes reach the egg-cell, I cannot say, having never seen a trace of them in the ovarial cavity, nor was there an indication of a stigmatic channel or a conducting-tissue. I was also unable to trace the early stages of the development of the embryo, as the smallest I came across was 3 mm. long and already distinctly differentiated (Pl. 45. figs. 22, 23).

There would therefore be a considerable gap in my account of the development of the fruit, but for the light which certain remarkable young fruits from the Garo Hills threw on the earlier phases. These fruits ranged from the earliest stages to that of almost complete maturity. They (Pl. 45. figs. 16-18) were mostly normal to all outward appearance, but never contained a trace of an embryo, representing evidently a case of imperfectly efficient fertilization, similar to that of seedless raisins, citrons, hops, or Crucifers †. Apart from the absence of an embryo and certain changes in the apex of the ovule immediately dependent on the presence of the embryo, the development of the fruits was no doubt essentially that of normal fertile fruits. The changes in the apex of the ovule just alluded to consist in its being crushed and obliterated by the growing embryo, which, as it enlarges, fills the bottom of the ovarial cavity and pushes its way towards the base of the fruit. No embryo having been formed in the barren Garo Hills fruits, the apex of the ovule took part in the general enlargement of the ovule until in one case it attained the considerable length of 4 mm. (Pl. 45. figs. 18, 19). Making, then, use of my observations on these fruits for the description of the earlier stages of the development of the fruit, I proceed now to give as far as possible a coherent account of it.

The ovule grows, after fertilization, simultaneously with the ovary. The ovarial cavity also expands, but chiefly longitudinally, so as to form a flat linear canal (fig. 16, *oc.**) in front of the embryo-sac. Yet, as the latter grows faster than the cavity expands, this canal is not only left behind in its longitudinal development, but is also gradually closed up, the obliteration beginning from the upper end. It remains, however, for a long time distinctly discernible as a narrow marked strip, situated along or somewhat aside of the middle line of the front half of the embryo-sac, and ascending to about $\frac{1}{2}$ to $\frac{2}{3}$ of its length. As the ovarial cavity closes up, the meeting surface layers of the front and back walls become more or less liquefied or jellified. How early the peripheral cells of the ovule-wall prepare for this change, I have already stated on p. 409. In consequence of this process the ovarial canal may be filled up with a structureless substance (Pl. 45. figs. 20 *oc.**, 21); but as a rule the walls coalesce without leaving a trace of their original separation, or only betraying it, in cross-sections, by somewhat thin bands with the appearance of solidified jelly. Whilst this is going on, endosperm (Pl. 45. figs. 20, 22, *end.*) forms as a delicate film, lining the embryo-sac with a layer of small almost isodiametric cells, which are followed inwards by larger radially lengthened cells (Pl. 46. figs. 30, 31). The thickness of the lining is, however, more or less unequal in different parts, so that its inner surface is very uneven (Pl. 45. figs. 20, 22, *end.*). Occasionally flake-like extensions of endospermatic tissue project far into, or even traverse, as thin strands or lamellæ, the cavity, which is filled with an almost limpid, slightly opalescent liquid. Apart from such exceptional expansions, the endospermatic lining grows rarely thicker than 1 mm., and often remains considerably thinner. The cell-walls of the endosperm are very thin, particularly those of the inner portions, which in some cases were found

† See Noll, "Fruchtbildung ohne vorausgegangene Bestäubung (Parthenocarpie) bei der Gurke," in Sitz.-Ber. Niederrhein. Gesellsch. für Natur- u. Heilkunde zu Bonn, 1902, p. 1. True parthenocarp is, in my opinion, out of question, considering that the *Melocanna* forests of the Garo Hills must have been full of pollen.

to be of extreme delicacy. The peripheral endosperm-cells are filled with plasma; the inner contain a decreasing amount of plasmatic wall-lining, and, beside their nuclei, a great deal of oil and a varying but moderate amount of transitory starch. A portion of the oil passes into the liquid filling the embryo-sac, leaving a greasy residuum if the liquid is evaporated. Small quantities of starch and free nuclei were also found in the liquid, probably escapes from cells which had been cut open. This was the condition of the embryo-sac of the young fruit which contained the smallest embryo I observed in the course of my investigations. The fruit measured about 2.5 cm. across where widest, whilst the embryo-sac was up to 1.2 cm. wide and 2 cm. long. The length of the embryo was 3 mm., as already stated, and its distance from the base of the fruit slightly over 3 mm. I may add that the pericarp at this stage contained scarcely any starch. The embryo occupied the base of the ovarial cavity, lying across it. The apex of the ovule was no longer discernible, having been crushed and probably in part absorbed by the growing embryo. The shape of the embryo (Pl. 45. figs. 22 & 23) at this stage was that of an ordinary grass embryo with a flat shield-like scutellum. Plumule and radicle had been formed and were in the peculiar position which I shall describe later on. Even the bud in the axil of the coleoptile and the initials of the first secondary roots were developed, whilst a considerable number of the protocambial strands could be traced from the base of the plumule into the scutellum. As the fruit continues to grow the embryo-sac and embryo enlarge. The embryo passes basewards and crushes the parenchyma below it, until it lies finally close to the surface covered by a coriaceous piece of dead tissue (Pl. 45. fig. 3, *et.*). This downward movement is facilitated by the spongy condition of the parenchyma at the very base of the young fruit. In the case figured on Pl. 45. fig. 22, a portion of it (fig. 22, at *) about midway between the embryo and the point of insertion of the stalk was even in a state of collapse. Analogous conditions occur also in other viviparous plants and have led to the adoption of the term "Verdrängungsgewebe" (see Goebel, in 'Flora,' lxxxiii. 1897, p. 430). Simultaneously the plumule develops more leaf-primordia, a few more secondary rootlets are formed, and the system of vascular strands gradually assumes the peculiar complicated structure characteristic of the mature embryo of *Melocanna*; but the most remarkable development is that which the scutellum undergoes. Growing from the back which is turned towards the cavity of the embryo-sac, it fills the cavity tightly from the base upwards, either entirely or with the exception of a small portion at the top. At the same time the liquid contents of the embryo-sac are absorbed and the endospermatic lining which has long before collapsed becomes wedged in between scutellum and pericarp and crushed into an apparently structureless (Pl. 46. fig. 29, *d.*) film. This growth of the scutellum is accompanied by the development of very numerous vascular strands (Pl. 47. figs. 40, 51) spreading in sheaf fashion from the base of the scutellum. Towards the close of the development reserve starch is deposited in the parenchymatic ground-tissue, whilst the epithelium (Pl. 46. fig. 29, *epth.*) remains from an early stage filled with plasma, proteids, and oil in tiny drops. Before the fruit attains its final size, the pericarp also begins to be charged with starch, with the exception of the innermost 3 or 4 cell-

layers, which contain a few minute grains of starch or none at all. Having reached this stage, the fruit may be considered mature. *As appears from the description, it consists of the fleshy pericarp and a naked "seed," the embryo proper lying outside the skinny covering of the diaphragm, or, what amounts to the same, the embryo-sac.*

VI. INTERNAL STRUCTURE OF THE FRUIT.

A. *The Pericarp.*

The outer epidermis (Pl. 46. figs. 24, 25) of the pericarp consists of isodiametric polygonal cells of no great depth, with a very limited number of irregularly interspersed stomata (Pl. 46. fig. 25). All the cell-walls, but particularly the side-walls, are considerably and often irregularly thickened and the latter perforated by numerous pits. In consequence of the somewhat unequal size of the cells, and still more of the unequal thickening and the numerous pits, the surface aspect of the epidermis is rather irregular and characterized by the unequally crenulated outlines of the cell-lumina. This irregular appearance is further enhanced by the frequent presence of silica-bodies (Pl. 46. fig. 26) in the cells, which often fill the lumina and make the cells appear solid. Mr. Boodle was good enough to examine for me the epidermis more closely for its silicification. Sections treated with phenol in the way described by Grobb ("Anat. d. Epiderm. Gramineenblätt.," in Bibl. Bot. vii. pp. 14-17) or with Eau de Javelle and clove-oil showed that the cells containing silica-bodies are arranged in irregular groups of sometimes considerable extent and varying shape, and apparently without any definite order (Pl. 46. fig. 26). These silica-bodies may be obtained free either by maceration in Schultz's liquid or by burning. The latter method has the advantage of retaining them in their position, which makes it possible to test the appearances obtained by treating the sections with phenol or clove-oil. This was desirable, as the silica-bodies show up in these media only on account of their particular coefficient of refraction. The silica-bodies are either approximately cubic or parallelopipedic or perfect casts of the cell-lumina, or more or less irregular and rarely quite solid, minute cavities appearing as pores or rents being the rule. Silicification of the cell-walls does not seem to occur, or only to a limited degree. The stomata possess semilunar guard-cells, flanked generally by very large subsidiary cells (Pl. 46. fig. 25), which are frequently perfectly filled up with silica. The whole epidermis, including the guard-cells of the stomata, is completely cuticularized.

Immediately below the epidermis, the tissue has a collenchymatic (Pl. 46. fig. 24) character. This zone is about 4-5 cell-layers deep, the cells gradually increasing inwards in size. They are tangentially slightly flattened and longest in the longitudinal axis of the fruit; they contain a considerable amount of plasma and chloroplasts, but little (the inner) or no starch. This collenchyma passes inward gradually into a parenchyma (Pl. 46. fig. 27) the cells of which are of very considerable dimensions, approximately isodiametric, pitted and filled with starch. This is present in ellipsoid or subglobose masses, composed of minute globose granules, 1-4 μ in diameter, and in isolated more or less ellipsoid granules of 6-8 μ in diameter. The compound starch-grains, however,

break up very readily into their components. The only other contents are a very faint plasmatic wall-lining and a very small quantity of oil. The cell-walls are rather thick and swell very much in a diluted solution of potassium hydrate. The ordinary reagents for cellulose show that the walls of this parenchyma as well as those of the collenchyma are of pure cellulose, with the exception of a thin central lamella. Towards the inner surface of the pericarp the elements of the parenchyma (Pl. 46. fig. 29, *p.*) decrease rapidly in size, being at the same time tangentially slightly flattened, whilst the cell-walls exhibit the same character as in the outer parts. The innermost layer which borders immediately on the diaphragm, and represents the inner epidermis, is in no way differentiated from the small-celled tissue immediately outside it, except in so far as the lumina are still more reduced and often irregular, as if the cells had been exposed to unequal pressure. This small-celled inner zone as a rule contains starch only in the outer layers and in the shape of minute granules; otherwise the principal directly visible cell-contents are plasma and some oil.

The whole of the pericarp is traversed by vascular strands (Pl. 45. fig. 5) which, seen in transverse sections, appear arranged more or less concentrically, being most numerous towards the periphery. They are directed from the base of the fruit upwards, branching here and there but not frequently, and consist chiefly of cambiform tissue and fine strands of tracheids. Most of them must have been formed during the growth of the fruit, as they are much more numerous than in the ovary.

The ribs of the fruit, where present, exhibit no special characters in their structure, but it is probable that the formation of the collenchyma starts from them.

B. *The Diaphragm.*

In describing the development of the fruit, I pointed out that the diaphragm of the mature fruit represents the collapsed and crushed remains of the rudimentary endosperm which develops in the earlier stages of the young fruit. Seen in a transverse section under a low power it appears as a thin zone distinctly marked off towards the embryo, but less so towards the pericarp, from which it differs mainly in its greater density, resembling somewhat hardened jelly. Its thickness varies slightly in different parts, but without any definite relation to the orientation of the embryo, from 15μ to 50μ or more. It separates readily from the embryo except near the base, but is so firmly attached to the pericarp that it cannot be removed, unless it is soaked for some time in water, when it swells and may be pulled off in fragments. This lining often appears, where it is thinnest, even under a higher power, almost homogeneous (Pl. 46. fig. 29, *d.*), with tangential lines of less density and, in places, a delicate tangential striation. On the other hand, if we examine it where it is widest, distinct cell-lumina of usually tangential extension may be seen, at least in the part nearest to the pericarp. If these sections are, however, left soaking in water or a very dilute solution of hydrate of potassium, or in Eau de Javelle, the tissue becomes gradually loosened, and with the aid of needles it may be so expanded as to restore approximately the original shape of the

cells (Pl. 46. figs. 30, 31) constituting the tissue, which in this condition may measure as much as 0.75 mm. in diameter. This means that, in its crushed state, it was compressed to $\frac{1}{20}$ to $\frac{1}{50}$ of its original thickness. In expanding this tissue, it always struck me that the outer and middle strata yielded much more readily to the needle than the innermost, which often remained in their compressed condition. The cells of the outermost two or three strata are the smallest and nearly isodiametric. They contain the scanty remains of the plasmatic wall-lining and of the nucleus. Farther inwards the cells increase rapidly, with their greatest diameter in the direction of the radius. They are completely empty or contain the vacuolate skeleton of a nucleus. All the cells of this tissue possess extremely delicate walls giving typical cellulose reaction, and are destitute of pits or any other sculpturing. What appears at first glance as tangential striation is nothing but the delicate folding of the completely crushed radial walls, and corresponds to the equally delicate undulation they exhibit in transverse sections (Pl. 46. fig. 32).

C. *The Embryo.*

The general structure of the embryo on the whole agrees with that of the typical grass fruit, with the exception of the enormous development of the scutellum, which either completely fills up the cavity of the pericarp or, towards the top, leaves a portion of it empty. We may distinguish the following parts in the embryo (Pl. 47. figs. 36, 44, 51):—(1) the plumule; (2) the coleorrhiza with the primary and several secondary roots within it, the whole corresponding to the “radicle” of descriptive botany; (3) the curiously modified and enlarged scutellum; and (4) the remaining portion of the embryo, constituting the hypocotyl. The most striking feature of the embryo next to the scutellum is the curvature of the embryo, which is so strong that the inner faces of the plumule and the radicle are contiguous. This is unique in grasses, although an approach to it may be seen in the curved embryos of *Oryza* and *Leersia*. It is evidently due to this condition that no trace of an epiblast is seen. Its place would be the inner angle of the bend, where there is no room for such an organ. These being the main features of the embryo, I will now proceed to describe the different parts more in detail.

1. *The Plumule* (Pl. 45. fig. 3, *pl.*; Pl. 47. figs. 36–40, *col.*).—The plumule has the shape of a short, somewhat oblique cone, and consists of a coleoptile with a bud in its axil, and about seven distinct young leaves and the rather flat growing point. The coleoptil (Pl. 47. figs. 44, 45) is open on the top and along a slit descending on the inner face which is contiguous with the radicle, the margins being minutely ciliate. According to Schlickum (“Morph. u. anat. Vergleich d. Keimpflanz. d. Monokotyl.,” in *Bibl. Botan.* vi. (1896) p. 68), the coleoptile of the grasses differs essentially from the leaves following it in the absence of stomata and the presence of only two vascular bundles. This is not the case in *Melocanna*, the coleoptile (Pl. 47. fig. 46) in these respects entirely resembling the leaves nearest to it. It possesses not only stomata and numerous vascular bundles, of which about 17–19 are of the first order, but the structure of the outer epidermis is much more complicated than might be expected.

For the epidermis (Pl. 47. fig. 55), besides having stomata, is differentiated into long and short cells ("Kurzzellen," Pfitzer) and two kinds of hairs, viz., fine, stiff-pointed, 1-celled bristles, and smaller, thin-walled, 2-3-celled, obtuse, club-shaped hairs, which are usually bent above the basal cell so as to lie more or less on the epidermis, corresponding to the "Winkelhaare" of Grobb ("Anat. d. Epiderm. Gramineenblätt.," in Bibl. Bot. vii. p. 20). As already mentioned, the coleoptile always bears a small bud (Pl. 45. fig. 23; Pl. 47. figs. 46-48, *b.*) with several distinct leaf-primordia in its axil, either opposite the radicle or more frequently slightly lateral. The first leaf after the coleoptile (fig. 46, *l.*) is exactly opposite to it, flattened and slightly 2-keeled on the back, not unlike an ordinary dorsal bract ("adossirtes Vorblatt," Eichler), a condition evidently due to the pressure of the radicle, and disappearing as soon as the leaf grows beyond it in the course of germination. Like the coleoptile, the first leaf possesses numerous vascular bundles. The second leaf is so placed that its median plane cuts that of the coleoptile and first leaf at an angle of 30° ; the third leaf is approximately opposite the second. The fourth diverges from the second by about 60° , and its median plane is therefore at a right angle to that of the coleoptile. The following leaves diverge approximately at an angle of 180° from the preceding leaf. The median plane of the coleoptile and the first leaf coincide therefore with that of the embryo, whilst the fourth and the following leaves of the plumule are placed at right angles to it, and the second and third leaves are in an intermediate position. I may add that the second leaf overlaps the third very distinctly on the outer side, whilst it is, though slightly, overlapped by it on the inner side (*i. e.*, the side towards the radicle). In the following leaves the overlapping is quite normal.

2. *The Radicle* (Pl. 45. fig. 3, *r.*; Pl. 47. figs. 36-43, *rad.*).—Like the plumule, the radicle has the shape of an oblique cone, but it is rather smaller. I have already mentioned that it consists, as is generally the case in Gramineæ, of a coleorrhiza, which is very large, a primary root (Pl. 47. fig. 46, *r. l.*), and a few secondary roots (Pl. 47. figs. 47, 51), which are arranged almost concentrically, and start at a level which corresponds to a cross-section from the inner angle of the embryo to the junction of scutellum and coleorrhiza on the opposite side. There is only one point in the structure of the radicle to which I wish to draw attention. As stated above, there is no epiblast in *Melocanna*, but on the outer side (*i. e.*, the side opposite to that where we would look for the epiblast) I once noticed a small scale (Pl. 47. figs. 39 *ex.*, 40) of the shape and structure of an epiblast, whilst in another case only an irregular swelling was perceptible. In a third seed I found a short obtuse protuberance placed somewhat laterally and projecting downwards. At first I thought it might correspond to some secondary root, but, in dissecting it, I found it to consist of the same parenchyma as the coleorrhiza, and that it was not correlated to any secondary root which was then discernible. Another peculiarity of the coleorrhiza is the presence of very fine though comparatively deep furrows (Pl. 47. figs. 39, 53), extending longitudinally on the upper and outer side. There is apparently no definite rule as to their number and position, and, so far as I was able to see, no distinct correlation to anything in the internal

structure of the radicle or of the scutellum up to which they may continue. I have no explanation to offer at present with respect to these appendages and furrows, but they seem to point to a certain plasticity of the coleorrhiza, and throw, perhaps, some light on the nature of the epiblast as an appendage of the coleorrhiza.

3. *The Scutellum*.—The scutellum (Pl. 45. figs. 3, 5, 7, *sc.*; Pl. 47. figs. 36–38, 51) is a large fleshy body, 20 to almost 40 mm. long, and 12 to 16 mm. in diameter where widest. It is oblong-ellipsoid, terete or slightly compressed at a right angle to the median plane. Its surface may be regularly curved, or slightly constricted about the middle, or faintly indented on one side. This indentation (Pl. 47. figs. 36, 37) corresponds to the upper end of the ovarial cavity, which in the mature seed is completely obliterated, but leaves occasionally traces in the moulding of the scutellum which fills up the cavity. At the base, the scutellum is slightly produced into a rim, so as to cover a part of the radicle and the plumule. The rim (Pl. 47. figs. 36, 37, 38, 40) may be two-lipped, as shown in Pl. 47. figs. 36 & 40, or it may be interrupted where the coleorrhiza scale overlaps the base of the scutellum (fig. 40). The epidermis of the scutellum is developed almost entirely as haustorial epithelium (Pl. 46. fig. 29, *epth.*), and agrees exactly with that of *Triticum* and other grasses. The cells are about twice as high as wide, thin-walled, not at all cuticularized, and full of plasma and proteids. Their outer walls, as a rule, bulge very little, although sometimes cells, or groups of cells, may be seen projecting beyond their neighbours; but they do not seem to grow out into papillæ, as is the case in certain other grasses. An exception to this epithelial modification of the epidermis, however, is to be found at the very base of the scutellum, mainly where it overlies the embryo proper. Here, over the edge as well as on the inner side of the reflexed rim, the epidermal cells are comparatively shallow, their outer walls thickened and covered by a delicate cuticle. They contain plasma, but only in moderate quantities. The bulk of the tissue of the scutellum consists of thin-walled parenchyma (Pl. 46. fig. 35) with plenty of interstices, the cells decreasing near the periphery. It is only in the basal rim that the parenchyma assumes a collenchymatic character. The cells are pitted, the pits being circular or oblong, and, owing to the thinness of the walls, of course very shallow. The cell-walls are of pure cellulose. The scutellum is traversed throughout its length and breadth by numerous vascular strands (Pl. 45. fig. 5, Pl. 47. fig. 51), which, entering at its base from the axis, spread like the halms of a loose sheaf, branching freely towards the periphery, and terminating in innumerable branchlets close to the epithelial surface, separated from it by not more than 2–3 layers of small parenchyma. They consist mainly of a delicate cambiform tissue, with slender strands of tracheids (Pl. 46. figs. 33, 34), and appear to possess no solid contents with the exception of some scanty starch in the outer parts. The tracheids disappear just below the ends of the strands, which terminate with a cap of cambiform tissue.

The Hypocotyl.—If we remove the radicle, plumule, and scutellum from the embryo, a portion of the latter is left which has approximately the shape of a piece cut out of a cylinder with an elliptical base by two oblique sections intersecting at an angle of 90°–100° just within one of the poles of the short axis. The line of intersection would

correspond to the inner angle of the embryo proper, the broad back of the cylinder fragment to the ideal contact-plane with the scutellum, whilst only a small portion of the cylinder surface, a triangular piece on each side, is left exposed; but even of these flanks, a considerable portion or the whole is overlapped by the deflexed rim of the scutellum. The epidermis of the hypocotyl resembles that of this rim. Below it there is parenchyma containing starch in quantities increasing in the direction towards the scutellum. The centre of the hypocotyl is, however, occupied by a plate (Pl. 47. figs. 40, 48, 51) consisting of a perfect tangle of vascular strands recalling the structure of mazerwood (Pl. 47. figs. 52, 53). This plate extends close to the outer base of the coleoptile on one side, and to near the root initials on the other. It is convex and well-defined towards the scutellum, but breaks up towards the plumule into numerous procambial strands going to the coleoptile and the leaf-primordia. Another set of vascular strands enters the scutellum, starting abruptly out of the dorsal surface of the plate. The structure of the strands is on the whole plain enough (Pl. 47. fig. 54). They consist of procambium with usually simple threads of tracheids. Only those which are situated towards the ends of the plate, that is near the outer base of the coleoptile and the root-primordia, show a higher differentiation, containing rows of wide cells with grate-like perforations (a kind of short-jointed vessels), thin-walled parenchyma more or less rich in starch, and subprosenchymatic portions with lignified thick walls and full of starch, and finally a slender strand of delicate phloem. The space between the tangled strands of the axil plate is occupied by parenchyma containing starch. This concludes the description of the internal structure of the fruit.

VII. GERMINATION.

I have already quoted Kurz's and Robinson's remarks concerning the germination of the *Melocanna* fruit on the tree (p. 402). There is no more recent account of this phenomenon, which is, with the exception of *Melocalamus*, apparently quite unique among grasses; their statements, more especially Robinson's, are, however, so precise and definite, that there can be no doubt that we have in *Melocanna* a remarkable example of vivipary. All the fruits of *Melocanna* which were at my disposal, with the exception of those from the Garo Hills, possessed a well-developed embryo, and in about half of them the radicle and plumule had already pierced the pericarp, the former having in several cases produced a bundle of secondary roots. But no fruit was gone so far as some observed by Kurz, who says of *Melocanna bambusoides* ('Indian Forester,' i. p. 268): "the fruits drop from the plant after they have made shoots some 6 inches long."

The first outward sign of beginning germination is that the embryotegium turns brown or black, and is lifted up like a lid by the tips of the plumule and radicle which appear simultaneously. They soon push the embryotegium aside; but it may still remain attached to the fruit for some time. Then the plumule (Pl. 45. figs. 6, 7; Pl. 47. figs. 41, 51) grows out; its young leaves burst through the coleoptile, and push out like the joints of a telescope. A small shoot is formed, densely covered by firm, rather thick, pubescent

cataphylls. As already remarked, this shoot may attain a length of 15 cm. before the fruit falls; but, as it seems, it develops scarcely any blades for some time, as Kurz says ('Indian Forester,' i. p. 268) "these shoots attained a height of 15 to 16 inches after only ten days that they were planted out in the ground, but had thrown out only two leaves:" a statement which is borne out by a drawing of a seedling in Gamble's herbarium.

Simultaneously with the plumule, the root-system develops. The primary and the secondary roots break through the coleorrhiza and grow rapidly into a bundle of thick root-fibres, among which the primary root is not readily distinguished, if it does not altogether die early, as seems frequently to be the case. Plumule and roots thus quickly outgrow the depression at the fruit-base from where they started, diverging at the same time. The scutellum, however, remains enclosed in the cavity of the pericarp, a neck being formed by intercalary growth at the base of the scutellum. This neck may attain a length of almost 10 mm. with a diameter of 4-5 mm. (Pl. 45. fig. 7; Pl. 47. figs. 41, 51). Longitudinal sections through a germinating fruit show this neck clearly, but they scarcely reveal any other macroscopically visible change in the scutellum and the pericarp, except in so far as in some cases certain peripheral portions of the pericarp, chiefly in the upper part, appear brown, a sign of decay. The microscopical examination of the pericarp, however, shows that the macroscopic changes in the germinating fruit are accompanied by the gradual exhaustion of the pericarp. The first sign of this exhaustion is the breaking up of the compound starch-grains, after which the starch disappears gradually. At the same time the outer lamellæ of the thick cell-walls of the parenchyma are dissolved, the walls appearing corroded all over, so that finally, in places, not much more is left of them than the central lamella. Whilst the depletion of the pericarp had already gone far in some of the fruits which were at my disposal, there was no change yet noticeable in the scutellum. This organ evidently remains active as long as there is any possibility of drawing on the pericarp, and its own exhaustion sets in only after the depletion of the pericarp.

Kurz's and Robinson's accounts of the germination of the *Melocanna* fruits on the tree (see p. 402) give the impression as if this condition was the normal state. No doubt it is of frequent occurrence, and may be the rule. Still the structure of the fruit is such as to justify the assumption that the young plant may just as well establish itself in the case of the fruit falling before germination has set in. In fact, Gamble states ('Indian Bambuseæ,' p. 120) that he grew young *Melocanna* plants from fruits which had not yet germinated when they were put in the soil. Nor should it be overlooked that the chances of injury to the shoot of germinating fruits when falling from a height of 40-70 feet must be very great, even if they fall into very soft soil. Unfortunately we know nothing as to the condition of the *Melocanna* forest at the critical time when its restocking takes place, nor have I been able to ascertain in what season the fall of the fruit occurs. So much, however, seems to be certain that the fruit once detached from the mother-plant does not stand a long delay, at any rate under the conditions to which it would be naturally exposed on the ground of the forest. There is apparently nothing in its

structure to prepare it for a period of rest and to protect it during that state. On the contrary, everything points to the immediate transition from maturation to germination, which is characteristic of all viviparous plants. It may be asked in how far the term "vivipary" is applicable to *Melocanna bambusoides*. Of course if we confine it to those cases where the embryo pierces the fruit whilst it is still in connection with the mother-plant, we could only speak of this bamboo as "facultatively viviparous;" but this does not seem to be correct. Where the fruit of *Melocanna* agrees with other fruits commonly admitted as viviparous is in the development of the embryo outside the embryo-sac and at the expense of the mother-plant. Whether the separation from the latter occurs, in *Melocanna*, before or after the actual piercing of the pericarp is not much more than an accident, possibly dependent on the weight of the fruit and the tensile strength of the fruit-stalk, or external factors, as storm or rain. The uninterrupted development of the embryo is practically safeguarded in both cases. The remarkable circumstance, however, in which this instance of vivipary differs from all the others known so far, is the ample supply of reserve food with which the seedling starts its independent life.

VIII. CONCLUSION.

I will now try to summarize the results of my investigations into the structure and the germination of the fruit of *Melocanna*, mainly with respect to the points in which it deviates from the typical grass fruit, and to examine how far these structural modifications are correlated with functional differences.

The ordinary grass fruit is small, indeed very small, compared with the fruit of *Melocanna*. The pericarp is dead; its functions are essentially mechanical, and it is accordingly developed as a thin crustaceous or skinny and dry shell which in the course of development has become adnate to the seed. The testa is a delicate and often obscure membrane, likewise dead, which is fused to the pericarp, and if it has any function worth mentioning it goes to strengthen the pericarp. The reserve materials required for the germinating embryo are deposited in the endosperm, which forms the bulk of the fruit. The embryo itself is usually small, although already well differentiated and free of starch, the scutellum acting merely as sucker on the endosperm. Maturity attained, the fruit separates from the mother-plant, and the embryo starts an independent life after a shorter or longer period of rest. All this is very different here. In *Melocanna* the pericarp attains relatively enormous proportions, remains fleshy, although rather hard and tough, and it has an active and very important share in the metabolism of the maturing and germinating fruit. Its functions are, in the first place, those of an ample reserve depot, the reserves consisting of the cell-contents as well as of the cell-walls. A well-developed system of vascular strands, spread through the pericarp in concentric arrangement, serves to convey and distribute the materials which go to build up, feed, and fill the growing fruit, and possibly also to supply the embryo with water if the fruit germinates whilst still on the tree. The strands enter the fruit at the base, where it is attached to the rhachilla that acts as fruit-stalk. This is, considering the size of the fruit and the amount of the nutritive matter and water which have to pass it, remarkably

slender (Pl. 45. fig. 4, *rh.*). It measures not more than 0.4–0.5 mm.² in cross-section, of which more than one half goes to the dry parenchymatic cortex, whilst the stereome and mestome of the central cylinder are approximately in the proportion of 3 : 1 (Pl. 47. fig. 57) *. It is true a portion of the products of assimilation deposited in the fruit has, no doubt, originated in the chlorophyll of the collenchyma of the pericarp; but it is not probable that this relieves the strain on the mother-plant as the main source of supply to any considerable extent, and the water in any case has to come entirely through the narrow channels of the stalk. The complete cuticularization and the thickening of the epidermis as well as its silicification must thus be a great aid for the plant in economizing the water-supply by reducing the transpiration to a minimum, at the same time contributing to the efficiency of the epidermis as a mechanical tissue. Mechanical is also the function of the collenchyma in so far as it provides for the necessary rigidity of the growing fruit, and in the mature state adds to the strength of the pericarp, resulting from the thick cell-walls of its parenchyma. Thus the deposition of a portion of the reserves as cellulose has incidentally a considerable mechanical effect in the direction of compressive strength, which is very important considering the height from which the fruits fall. Otherwise, however, there is little in the pericarp to protect it and the enclosed seed for any length of time from the attacks of the animal and vegetable world and destructive atmospheric influences. The *Melocanna* fruit is evidently not built for a lengthy period of rest. To speak of the seed, we have seen that it is naked. In fact, the term "seed," in the usual sense, is scarcely applicable to it. There is, *ab initio*, no integument to form a testa, and the free ovule-wall corresponds to so small a fraction of the full-grown embryo-sac, and is lost so completely in the pericarp, that any function the testa has in the ordinary grass-seed, be it in the nascent or the final state, must devolve on the pericarp. So far as they are purely mechanical they are, in the presence of the powerful pericarp and the absence of a resting period, certainly a negligible quantity. On the other hand, if the nascent testa of the typical caryopsis, that is the inner integument of the maturing seed, acts as passage or transfusion tissue in the sense of Tschirch's 'Nährschicht' †, this function is taken over by the innermost layers of the pericarp, which supply immediately the maturing seed with water and nutrient matter. The typical store-organ of the fruit of the Gramineæ is the endosperm. In *Melocanna* endosperm is formed, but its formation does not go much beyond the initial stages. It is soon exhausted, collapses, and is finally crushed into an apparently structureless film, wedged in between pericarp and scutellum. To compensate the loss of the endosperm, the storage of nutrient matter is shifted on partly to the pericarp, partly to the scutellum, and cellulose has been added in the former to the usual reserve materials of the grass-seed. Curiously enough, the normal

* The dimensions measured in a typical case were:—cross-section, just below the flowering glume, 0.44 mm.²; cortex 0.232 mm.²; central cylinder 0.206 mm.²; stereome 0.149 mm.²; mestome 0.0574 mm.² The fruit was fully developed and of average size.

† See Tschirch, 'Angewandte Pflanzenanatomie,' p. 459; and Holfert, "Nährschicht der Samenschalen," in *Flora*, 1890, pp. 279–313.

disposition of proteids and starch in the grass endosperm, namely, proteids in a peripheral layer and starch in the remainder, has found a parallel in the scutellum of *Melocanna*. But "obliterated" as the endosperm may be, and reduced to the state of a diaphragm, it is certainly not without its share in the economy of the *Melocanna* fruit. Sachs, in his paper on the germination of the grasses ("Zur Entwicklungsgeschichte der Gräser," Botan. Zeit. xx. 1862, p. 146) pointed to the presence in certain grasses of an obliterated tissue between the starch containing endosperm and the scutellum, and he showed that it was a depleted portion of the endosperm. Tschirch called this tissue "Quellschicht" (Tschirch & Oesterle, Anatom. Atlas, p. 184, Q in fig. 17 of pl. 42), a name which appears to me not well chosen, as it is neither analogous nor homologous to what German botanists ordinarily call "Quellschicht," *i. e.*, the mucilaginous layers in the testa of seeds, e. g. *Linum* or *Salvia*. As this obliterated tissue seems to be a rather common occurrence in seeds also outside the order Gramineæ, a more appropriate term is desirable, and it seems to me that this tissue might be conveniently designated as "diaphragm." It is clear that in seeds possessing such a "diaphragm" the food reserves of the endosperm have to pass the diaphragm in solution, but its actual functions are still obscure. Possibly it acts as a kind of filter. In a way analogous to that described by Sachs, the diaphragm of *Melocanna* is interposed between the store-organ (or rather one of the store-organs) and the scutellum, and its functions are no doubt also similar.

Although the scutellum has replaced the endosperm to some extent, it has not lost its original character as haustorium. It has rather increased in bulk and sucking surface, and become equipped with a highly developed system of mestome strands for the conveyance of the reserve materials to the fast growing embryo. In accordance, however, with the changed structure of the *Melocanna* fruit, it directs its energies towards the starch-filled pericarp, inducing there those chemical changes which result in the break-up and the disappearance of the starch, the greater portion of the cell-walls, and the remainder of the cell-contents generally. The carbohydrates pass through the inner cell-layers of the pericarp and the diaphragm most likely as glucose, the proteids as asparagine. The presence of the latter in the diaphragm and in the small cavity left occasionally between it and the scutellum was strikingly demonstrated in some fruits which had been sent in alcohol and had just started germinating when collected. In them the asparagine had crystallized, the crystals being either embedded in the diaphragm or attached to its inner surface, or sometimes to the surface of the scutellum. They were fairly numerous and up to 2 mm. long. Those which were found on the scutellum could easily be taken up, otherwise they had to be scraped or pulled from the diaphragm. The occurrence of the crystals suggested, under the circumstances, at once the presence of asparagine, and their solubility in water, as well as their behaviour when heated, seemed to confirm my assumption. To make quite sure, I sent a quantity of crystals to my friend Professor Hans Molisch, of Prague. He subjected them to further tests with the same result, and, finally, Mr. G. F. H. Smith, of the Mineralogical Department of the British Museum, determined them crystallographically as levo-asparagine.

We have still to consider the embryo proper (the embryo minus the scutellum). It

can scarcely be said that it is more differentiated or more advanced in development before it leaves the fruit than the embryos of a good many typical grasses; but it is much larger and possesses a more highly-developed vascular system. It differs further in its pronounced curvature, which results in the immediate juxtaposition of plumule and radicle, and in the similarity of the coleoptile and the leaves following it. The increased size of the embryo corresponds evidently to the increased bulk of the fruit, whilst both determine the copious supply with vascular strands. As to the curious curvature of the embryo, it appears to be connected with its downward movement in the growing fruit, from the point of origin in the interior to its final external position. By curving in this way it offers the minimum of surface to the tissue which is to be displaced, securing at the same time the simultaneous egression of radicle and plumule when germination sets in. The unusual structure of the coleoptile might similarly be explained by its peculiar function as the first of a succession of cataphylls which cover the axis of the seedling much as the sheaths, or "imperfect leaves," of the stolon-shoots cover and protect their axes.

Conditions as to which we have nothing to proffer but conjectures have so modified the evolution of *Melocanna* that its fruit has become viviparous. We know practically nothing about the ecology of the *Melocanna* forest; but so much is clear, that the immediate transition from maturation to germination and the particular fitness and readiness of the embryo plant to establish itself—conditions implied in vivipary—must give the seedlings of *Melocanna* a certain superiority in the struggle with the numerous intruders which, in a tropical country full of conditions favourable for plant life, are sure to invade the ground as soon as the *Melocanna* jungle is fallow and dead. Vivipary in itself does not, of course, necessarily mean a large seed or fruit, but if we consider that the seedling of *Melocanna* attains a considerable size before it forms perfect leaves ready to assimilate, we shall understand why they are, in addition to their vivipary, so abundantly supplied with reserve food. All this necessarily means a large fruit, but also an increased surface for the scutellum, as the organ which induces the solution of the stored nutrient matter and its transmission to the growing parts; but increased surface is bound up with the development of a bulky body, of which only a limited portion can be utilized for the formation of vascular strands, the channels of building matter and water transport. The rest will be fundamental tissue, and it is only an instance of economy if we find in *Melocanna* this tissue acting as store-tissue in addition to the much ampler depot formed of the pericarp. The absence of a period of rest, and the consequent uselessness of a protective fruit- or seed-shell, made the pericarp available for the storage of the reserve materials coming from the mother-plant or in part formed almost *in situ*. The same reasons, if I may say so, allowed the plant to dispense with the testa (generally prone to reduction in Gramineæ); and affecting still earlier phases in the ontogeny of the seed, they led to the suppression of the integument and the general reduction of the ovule. Hence the naked ovule and, at the other end of the line of development, the naked seed, if "seed" we may call it. Endosperm is still formed; but deprived of its normal function it collapses early, its empty crushed tissues acting as a "diaphragm" between the peri-

carp (to some extent the physiological equivalent of the endosperm of the typical grass seed) and the haustorial epithel of the scutellum. In this way, we may imagine, the *Melocanna* seed has become endospermless or "ex-albuminous." With the growth of the rudimentary ovule, as a distinct entity within the fruit, soon ceasing, the embryo-sac develops outside the ovarial cavity in the body of the ovary. It retains, however, only the scutellum, whilst plumule and radicle at an early stage burst its bonds and push their way to the fruit-base. Thus we have in *Melocanna* a case where deep going structural modifications and a corresponding transference of functions have taken place in the evolution of a most essential organ, otherwise so uniform in the order, with the result of securing under very different conditions that complete harmony in the economy of the organism which is the fundament of its existence.

It will be asked what light the structure of the *Melocanna* seed throws on that much discussed question of the morphological value of the scutellum, the coleoptile, and the epiblast. Highly specialized types, like *Melocanna*, rarely help us in the elucidation of obscure homologies. In this case, it is true, the differentiation of the embryo was little affected by the great modifications which the *Melocanna* fruit has undergone; but if they have not obscured or suppressed any of the essential features of the grass embryo, they have also not brought to light new traits either to confirm or to refute Schliekum's and Goebel's conception of the grass embryo, which, to my mind, is the only one that is really rational if we insist on reducing the monocotyledonous embryo to one definite type.

EXPLANATION OF THE PLATES.

PLATE 45.

- Fig. 1. Mature fruit, seen in the position as it hangs on the tree: *et.*=embryotegium. ($\frac{9}{10}$.)
 2. Mature fruit, side view: *lr.*=lateral ridge; *vr.*=ventral ridge. ($\frac{9}{10}$.)
 3. The same, in longitudinal section: *p.*=pericarp; *d.*=diaphragm; *sc.*=scutellum; *et.*=embryotegium; *pl.*=plumule; *r.*=radicle. ($\frac{9}{10}$.)
 4. Mature fruit, from below: *pa.*=palea; *va.*=valve; *rh.*=rhachilla (fruit-stalk). ($\frac{9}{10}$.)
 5. The same, in cross-section: letters as in fig. 3. ($\frac{9}{10}$.)
 6. Germinating fruit. ($\frac{9}{10}$.)
 7. The same, in longitudinal section, roots cut: letters as in fig. 3. ($\frac{9}{10}$.)
 8. Young hermaphrodite flower, front view: *pa.*=palea; *l.*=lodicule; *st.*=stamens; *pi.*=pistil. (4×.)
 9. The same, with the palea and stamens removed, back view: *rh.*=rhachilla (continuation): *l.* and *pi.* as in fig. 8. (4×.)
 10. Mature female flower with barren stamens, no lodicules. (4×.)

- Fig. 11. Fertilized ovary with palea and rhachilla continuation, side view : *pa.*=palea ; *rh.*=rhachilla. (4×.)
12. Lower part of a fertilized pistil in longitudinal section : *rh.*=rhachilla continuation ; *pa.*=palea ; *fil.*=filament ; *o.*=ovule ; *es.*=embryo-sac (indicated by the dotted line). (16×.)
13. Fertilized ovary in cross-section (spirit-material) : *vr.*=ventral ridge, opposite the palea ; *oc.*=ovarial cavity ; *o.*=ovule ; *es.*=embryo-sac. (27×.)
14. Fertilized ovule (from fig. 13), more magnified : *oc.*=ovarial cavity ; *ow.*=ovary-wall, outer layers (*) staining yellow with Schultz's solution, inner layers (**) staining blue ; *es.*=embryo-sac. (200×.)
15. Fertilized ovary in cross-section from herbarium material, microtome section, made by Mr. Boodle : letters as in fig. 13. (27×.)
16. Barren fruit, in longitudinal section, at a right angle to the median plane : *es.*=embryo-sac ; *d.*=diaphragm ; *oc.**=marking indicating the position of the obliterated ovarial cavity. ($\frac{9}{10}$.)
17. The same, in cross-section : fig. as in 16. ($\frac{9}{10}$.)
18. Another barren fruit, in longitudinal section in the median plane : *oc.**=obliterated ovarial cavity ; *ao.*=apex of ovule ; *es.*=embryo-sac. ($\frac{9}{10}$.)
19. Lower portion of ovule (from fig. 18) : letters as in fig. 18. (4×.)
20. Part of the cross-section represented in fig. 17 : *p.*=pericarp ; *oc.**=obliterated ovarial cavity, filled with a structureless mass ; *end.*=endosperm, almost collapsed ; *ow.*=ovary-wall. (27×.)
21. Part of the same, more magnified : letters as in fig. 20. (160×.)
22. Lower part of a semi-mature fruit : *p.*=pericarp, at * spongy and collapsing ; *es.*=embryo-sac ; *end.*=endosperm, at ** stretching across the cavity, indicating the level at which the embryo formed originally ; the apex of the ovule has quite disappeared : *e.*=embryo. (3×.)
23. Embryo of the fruit represented in fig. 22 : *co.*=coleoptile with a bud (*b.*) in its axil, its base covered on one side by the projecting rim of the scutellum (*sc.*), on the other by the radicle (*r.*) ; *sr.*=secondary root initial. (16×.)

PLATE 46.

- Fig. 24. Epidermis and collenchyma of the pericarp : *chl.*=chloroplasts ; *am.*=starch. (400×.)
25. Epidermis (surface view) with stoma : silicified guard-cells. (400×.)
26. Epidermis treated with Eau de Javelle and embedded in clove-oil : only the silicified cells are visible. (400×.)
27. Parenchyma from the middle of the pericarp, before germination ; the contents of one cell only are shown : *amc.*=compound starch-grains ; *ams.*=simple starch-grains. (400×.)
28. Parenchyma from the middle of the pericarp, germination advanced ; cell-walls partly dissolved and corroded. (400×.)
29. Innermost part of the pericarp, diaphragm, and outer part of the scutellum : *p.*=pericarp ; *d.*=diaphragm ; *sc.*=scutellum ; *epth.*=epithelium ; *am.*=starch. (400×.)
30. Outer part of the diaphragm (obliterated endosperm), expanded. (400×.)
31. Portions of the inner cells of the diaphragm, expanded, from a semi-mature fruit with transitory starch. (400×.)
32. One of the crushed inner cells of the diaphragm, imperfectly expanded. (400×.)
33. Vascular strand of the scutellum, in cross-section : *ca.*=cambiform ; *tr.*=tracheids. (×400.)
34. Vascular strand of the scutellum, near the surface, somewhat obliquely cut : letters as in fig. 33. (400×.)
35. Parenchyma from the centre of the scutellum : *am.*=starch ; *pi.*=pits. (400×.)

PLATE 47.

- Fig. 36. Complete embryo: *col.*=coleoptile (plumule); *rad.*=radicle; at * ridge corresponding to the obliterated ovarian cavity. ($\frac{9}{10}\times$)
37. The same, seen from the side: letters as in fig. 36. ($\frac{9}{10}\times$)
38. The same, seen from below: letters as in fig. 36. ($2\times$)
39. Plumule and radicle of an embryo with the overlapping rim of the scutellum removed: *ex.*=epiblastoid excrescence of the coleorrhiza; other letters as in fig. 36. ($4\times$)
40. The same, in longitudinal section, but the embryo still enclosed in the pericarp: *p.*=pericarp; *et.*=embryotegium; *col.*=coleoptile; *r.*=radicle. Above the plumule the central plate of strands, sending out diverging strands into the scutellum; in the axil of the coleoptile a small fragment of the base of a bud. ($4\times$)
41. Embryo in the first stage of germination: *scn.*=neck of the scutellum; other letters as in fig. 36. ($\frac{9}{10}\times$)
42. Plumule and radicle of the same embryo. ($4\times$)
43. The same, seen from the other side: letters as in fig. 36. ($4\times$)
44. Plumule seen from the inner side, radicle removed: *co.*=coleoptile; *rad.*=base of radicle. ($4\times$)
45. Top of the coleoptile of the same, showing the ciliolate margins. ($4\times$)
46. Cross-section through a plumule and radicle: *b.*=bud; I-VII=leaves of the plumule enveloped by the coleoptile; *coz.*=coleorrhiza; *r. I*=primary root. ($16\times$)
47. Cross-section through the base of the plumule and radicle: *b.*=bud; *co.*=coleoptile; I=part of the first leaf of the plumule. ($4\times$)
48. Cross-section through the embryo near the base of the neck; strand-plate of the hypocotyl shaded: letters as in fig. 47. ($4\times$)
49. Cross-section through the base of the neck: *p.*=a fragment of the pericarp; the dots indicate the vascular strands going to the scutellum. ($4\times$)
50. Cross-section through the narrowest part of the neck. ($4\times$)
51. Longitudinal section through a germinating embryo; most of the inner leaves of the plumule removed, roots cut. ($2\times$)
52. Longitudinal section through the upper part of the axil plate of the hypocotyl; the dark portions indicate parenchyma containing starch. ($27\times$)
53. A portion of the cross-section represented in fig. 48, showing a part of the axil plate of the hypocotyl in tangential section; on the right-hand side furrows descending towards the radicle. ($16\times$)
54. Procambial strands, from the axil plate, in cross-section: *am.*=starch containing parenchyma, corresponding to the shaded parts in fig. 52. ($200\times$)
55. Epidermis of coleoptile with a bristle and a "Winkelhaar" (surface view). ($400\times$)
56. Epidermis of the neck of a germinating embryo, in longitudinal section. ($400\times$)
57. Cross-section of a fruit-stalk (rhachilla), close below the valve (floral glume): *cort.*=cortex; *mest.*=mestome strands; *ster.*=stereome. ($55\times$)

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