and composed usually of four, more rarely of two or three roundish, opaque grains.

2904. **T. angustifolia** L. (Knuth, loc. cit.)—The flower mechanism of this species is the same as that of the preceding one. Unisexual plants have not yet been observed.

2905. **T. minima** Hoffm. (= T. Laximanni *Lepech.*). (Kerner, 'Nat. Hist. Pl.,' Eng. Ed. 1, II, p. 313.)—Kerner says that the interval between the maturation of the female and male flowers in this species is about nine days.

938. Sparganium L.

Protogynous, monoecious wind flowers, arranged in globular spikes. Warnstorf describes the pollen-grains as of the same size and shape in all the species, yellowish in colour, rounded, tetrahedral, with a network of tubercles, on an average 20 μ in diameter.

2906. **S. ramosum** Curt. (=S. erectum *L.*). (Kirchner, 'Flora v. Stuttgart,' p. 83; Knuth, loc. cit.)—The globular female spikes in this species are situated below the male ones and mature before them; the stigma begins to shrivel when the anthers of the small male spikes dehisce. The anthers are one mm. long and are adnate to movable filaments about 3 mm. long. Each male spike possesses some hundred stamens, and each female one 100–150 stigmas. Pollination is easily effected by the wind, because the stigmatic branches are 3 mm. long, situated on a style 2 mm. high, and therefore project widely. The diameter of the female spike is thus increased to $1\frac{1}{2}$ cm.; that of the male one is only about half as much.

2907. **S. simplex** Huds. (W. J. Behrens, Flora, Marburg, New Ser., xxxvii, 1879; Knuth, loc. cit.)—The flower mechanism in this species is the same as that of the preceding one, but the male and female spikes are smaller, and composed of fewer flowers.

CXX. ORDER *AROIDEAE* JUSS.

LITERATURE.—Engler and Prantl, 'Araceae,' in 'D. nat. Pflanzenfam.,' II, 3, pp. 108–9; Knuth, 'Grundriss d. Blütenbiol.,' p. 94.

The hermaphrodite or unisexual flowers are closely crowded on a fleshy axis, and form a spadix generally surrounded by a spathe. Insects are attracted partly by this, partly by the inflorescence, and partly by a coloured, club-shaped elongation of the spadix, or by several of these simultaneously.

939. Arum L.

Monoecious, protogynous, pitfall flowers.

2908. **A. maculatum** L. (Delpino, 'Ult. oss.,' pp. 17–21; Hildebrand, Bot. Ztg., Leipzig, xxviii, 1870, pp. 589, 591; Herm. Müller, 'Fertlsn.,' p. 562; MacLeod, Bot. Jaarb. Dodonaea, Ghent, v, 1893, pp. 292–3; Kirchner, 'Flora v. Stuttgart,' p. 86; Christy and Corder, 'Arum maculatum'; Knuth, 'Bloemenbiol. Bijdragen.')—In this species the upper part of the spathe, together with the thick, dark-red end of

the spadix projecting from it, serve to attract minute midges, particularly those of the genus Psychoda. The decomposing, urinous smell of the inflorescence during anthesis is a further attraction. The ventricose lower part of the spathe forms a temporary prison for the small visitors. As they creep downwards on the projecting, red-brown end of the spadix, they reach several rows of stiff bristles situated close above one another at the top of the contraction in the spathe, which stretch from the narrowed spadix to the inner surface of the spathe. The midges creep through them in order to reach the warmth and the red-brown colouring of the inner surface of the spathe, which from this point widens into a pit. They cannot at once escape from this. The threads would not hinder their creeping back through them, but the insects try to fly out, and fail to escape by this means, as they are only struck back by the fence of bristles when they fly towards the bright upper part of the pit.

The small prisoners find the mature stigmas in the first stage of anthesis, and deposit foreign pollen upon them in the attempt to gain the open once more. The stigmas then shrivel up, and in the place of each appears a minute drop of nectar, as compensation to the insects for their delay and their work of pollination. The anthers now dehisce and let their pollen escape, so that it fills the base of the pit, and the small visitors are dusted with it. Meanwhile the bristles barring the entrance have become limp, and the spathe opened out, and the visitors can now leave their temporary prison without difficulty. I have often observed that on cutting open a spathe the midges immediately fly to another plant and again creep down into the trap. On leaving the flower, therefore, they will go to another, and dust the stigmas with the foreign pollen.[1]

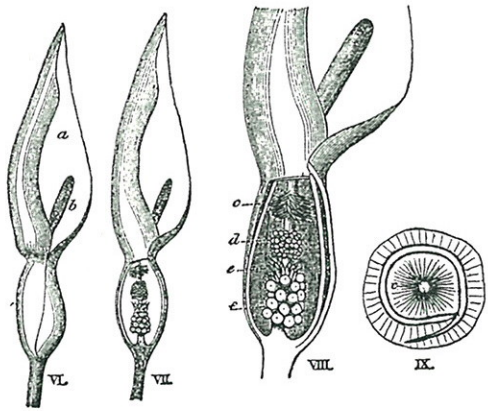

FIG. 410. *Arum maculatum*, *L.* (after Herm. Müller). VI. External view of inflorescence. VII. Do., with the trap cut open (×½). VIII. Do. (almost natural size). IX. Transverse section just above the trap-hairs. *a*, Upper part of spathe; *b*, dark-purple tip of the spadix, serving as an attraction and conducting-rod; *c*, trap-hairs (vestigial stamens); *d*, still immature male flowers (anthers); *e*, vestigial female flowers (ovaries), without any known function, possibly degenerate by correlation of growth with the upper stamens; *f*, female flowers (ovaries), in a receptive condition.

[1] After completing my manuscript I have written as follows in the 'Illust. Zs. für Entomologie,' iii, 1878, p. 201 :—I had already found hundreds of specimens of Psychoda phalaenoides *L.* in the trap of Arum maculatum *L.*, at Iserlohn in Westphalia, and at Eutin. But in plants sent me on June 8 of this year from the Castle Garden of Plön I have observed a larger number of these little midges than I have previously seen. The traps were so full of them that free movement must have been impossible, so closely were they packed together. In one trap there were no less than 6 cc. of midges. These I spread out as evenly as possible on a surface of one sq. m., and counted those occupying one sq. cm. as being forty on an average. There must, therefore, have been some 4000 midges in all within one trap.

The extraordinary eagerness with which these midges visit the inflorescences of Arum is shown by

Visitors.—Herm. Müller often observed hundreds of individuals of Psychoda phalaenoides *L.* (identified by Winnertz, and = P. nervosa *Mg.*, perhaps also Tipula nervosa *Schr.*). I have also noticed similar numbers of the same species in woods near Eutin.

2909. A. italicum Mill. (Delpino, op. cit.; Knuth, 'Blütenbiol. Beob. a. d. Ins. Capri,' pp. 16–21.)—The flower mechanism in this species corresponds exactly to that of A. maculatum. While in the bud stage the inflorescence is firmly surrounded by the large spathe, which is still green in colour, this gradually becomes lighter and its upper part unfolds so that the yellow tip of the spadix becomes visible. In the mature stage the spadix of plants in Capri reach a length of 8 or even 10 cm., and two-thirds or three-quarters of it are yellow in colour and up to 1·5 cm. in diameter, while the lowest third or quarter is contracted into a sort of stalk 6 mm. long and concealed in the narrow part of the spathe.

Below the narrowest part of the spadix there are several whorls of vestigial flowers, attached to a thickened region, and produced into stiff bristles 5 mm. long and directed obliquely downwards. They touch the wall of the trap. A piece of the spadix only a few millimetres long divides them from the numerous male flowers, arranged in 5–7 whorls, and each consisting of but a single stamen. Immediately below these are situated several whorls of vestigial female flowers with almost vertical style-like processes about 5 mm. long, and finally, below these, the female flowers, also arranged in 5–7 whorls. Each of the latter consists only of an ovary directed obliquely upwards, with a stigma on the outer side, which has the appearance of a roundish spot not quite one mm. in diameter.

The female flowers mature before the spathe opens, while the male ones do not shed their pollen until after the ovary has shrivelled. The stigma, hitherto of a whitish-yellow colour, scarcely distinguishable from the ovary in colour, is then of a brownish tinge, while a large mass of pollen fills the base of the trap. After the anthers have scattered the pollen, the spathe fades, and the upper, yellow part of the spadix then usually falls off. When the trap-hairs shrivel, the lower narrowed part of the spadix with the female flowers falls off also, the spathe withers entirely, and the fruits ripen.

Arcangeli (Nuovo Giorn. bot. ital., Firenze, xv, 1883) states that the inflorescences open towards 1 p.m. and reach full maturity between 3–5 p.m. The stages of maturation are the same as those of Dracunculus vulgaris *Schott.* The odour is not perceptible. Arcangeli describes it as a mixed smell of mice, lemon, and decayed vegetable matter. The spathe also possesses an odour of magnolia or fruit at its base.

The pollinators are small flies which feed on decayed vegetable matter. Arcangeli counted 239 small Diptera in 56 inflorescences, 159 of them belonging to the genus Psychoda. Only 17 were dusted with pollen, the others having already deposited theirs on the stigma.

With regard to the flowers of A. italicum, Arcangeli states that the increase of

the fact that, when a trap was cut open, all the contained insects flew out and made their way into the trap of a second specimen held in readiness. It must be added that all the Arums so filled with Psychoda were in the second (male) stage of anthesis, with shrivelled stigmas and dehiscing anthers.

temperature is perceptible at 9 a.m., several hours before the opening of the inflorescences: the maximum, 40° C., is reached between 6–8.30 p.m. The spadix loses weight considerably during the increase.

Kraus (Abh. nat. Ges., Halle, xvi, 1884, pp. 35–76) observed that the evolution of heat inside the spathe rises to 40–44·7° C. in an air temperature of 17·7° C. This increase of temperature usually begins at the tip of the spadix, and spreads thence to its base. The oecological significance of this increase is that it induces the pollen-transferring midges to descend into the warm trap. As the visitors use the tip of the spadix as an alighting-platform, this becomes warm first and most strongly. The increase of temperature only takes place during the first (protogynous) stage of the inflorescence, and ceases when this is over.

Visitors.—The following were recorded by the observers, and for the localities stated.—

Delpino ('Ult. oss.'), 6 Diptera (identified by Rondani)—1. Ceratopogon pictellum *Rond.*; 2. Chironomus byssinus *Schr.*; 3. Drosophila funebris *F.*; 4. Limosina pygmaea *Zett.* (= L. crassimana *Hal.*); 5. Psychoda nervosa *Schr.*; 6. P. nervosa *Mg.*; Knuth (Capri), numerous minute Diptera, and a staphylinid 4 mm. long.

2910. A. ternatum Thunb. (= Pinellia tuberifera *Tenore*). (Breitenbach, Bot. Ztg., Leipzig, xxxvii, 1879, pp. 687–92; Herm. Müller, 'Fertlsn.,' p. 564.)—The inflorescences in this species are protogynous. The pollen of the male flowers falls upon the small imprisoned insects (probably flies) which can then escape by a small opening.

2911. A. crinitum Ait. (Schnetzler, C.-R. Acad. sci., Paris, lxxxix, 1879, pp. 508–10.)—The flower mechanism of this species resembles that of A. maculatum. Carrion-flies are attracted by a strong smell of putrefying flesh. The smaller visitors cannot escape from the trap, but are held there firmly by sticky hairs and digested by their secretion.

Arcangeli (Nuovo Giorn. bot. ital., Firenze, xv, 1883) observed flies more particularly as visitors; in one spathe there were 385 Diptera, 107 of them belonging to the species Lucilia caesar *L.* The upper part of the spathe is bent like a knee, so that only the lower part forms the 'bridal chamber.' The upper part bears closely situated purple-red weel-bristles, directed obliquely downwards. The stigmas are as short-lived as those of Dracunculus vulgaris.

The plant is therefore adapted for pollination by Diptera. Such crowding of visitors into a single spathe as Arcangeli observed probably does not occur in a natural state; but in the plants examined was the result of the small number cultivated. This excess of visitors is indeed injurious to the plant, as they injure one another and die in the 'bridal chamber,' only a small number therefore emerging again during the fourth stage of anthesis.

2912. A. pictum L.—Arcangeli (Ric. ist. bot., Pisa, Fasc. 1, 1886, pp. 108–9) found 95 insects in one inflorescence in the Pisa Botanic Garden, consisting of 86 Borborus (Copromyza) equinus *Fall.*, 3 Aphodius melanostictus *Schmidt*, an Oxytelus nitidulus *Grav.*, 4 other smaller flies, and one hymenopterid (probably a parasite of Borborus).

The visitors were plainly attracted by the dark-purple colouring of the spathe

and the end of the spadix, and by the smell of the inflorescence, which resembles that of decaying fruit.

Martelli (Nuovo Giorn. bot. ital., Firenze, xxii, 1890, p. 129) adds that the protogynous inflorescences open in the morning. The stigmas are then receptive, but the anthers have not yet dehisced. The faecal odour is at its strongest in the upper part of the spadix, on which visitors alight. On the following day the anthers dehisce; the male flowers are situated on an inflorescence covered by a hood-like spathe.

2913. **A. Dioscoridis** Sibth. et Sm.—Caleri says that the spathe in this species opens early in the morning; between 8–9 a.m. it is visited by numerous flies (particularly muscids). The spathe then closes, the odour disappearing at the same time. On the second day the prisoners are set free. The stigmas of the protogynous flowers are therefore receptive for a very short time only.

940. Arisarum Targ. Toz.

2914. **A. vulgare** Targ. Toz. (= Arum Arisarum *L.*). (Delpino, 'Ult. oss.,' pp. 21–2; Knuth, 'Blütenbiol. Beob. a. d. Ins. Capri,' pp. 18–25.)—While in the island of Capri during March 1892 I could not observe the first stage of anthesis of this interesting species, because the plant was too far matured, but the flower mechanism was still easily distinguishable. Insects are attracted by the striped spathe and the projecting end of the spadix, and are temporarily imprisoned. At an early stage these two organs are of a greenish colour, the spathe below its arched tip being greenish with white longitudinal streaks. In a later stage the curved tip of the spadix, projecting 1·5–2 cm., is of a faint brownish tinge, and the hitherto greenish parts of the spathe assume the same colour, so that the upper, arched part of it appears to be brown, and the lower, cylindrical part is marked by about twenty brown and white streaks. Insects are attracted to the nectar, however, by the offensive, putrid smell of the inflorescence.

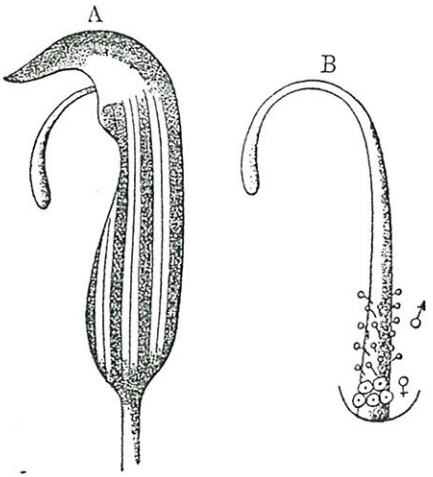

FIG. 411. *Arisarum vulgare*, *Targ. Toz* (from nature). *A*. Inflorescence with spathe intact. *B*. Do., after removal of spathe.

The spathe is about 4 cm. high, and the same in circumference. It is slightly contracted above, and roofed over by a pointed, dark-coloured lobe, bending over like a helmet, which keeps light from penetrating into the trap.

About ten female flowers are situated at the base of the spadix. Above them, loosely arranged for a distance of 1·5 cm., are the much more numerous (up to 40) male flowers, each consisting of a single short-stalked anther. The inflorescence is

protogynous, but the stigmas are still receptive when the anthers dehisce, so that autogamy is possible by fall of pollen. The insects attracted reach the trap either by creeping along the projecting spadix or along the inner surface of the spathe.

As a rule they are unwillingly detained there for some time, because they cannot find the opening again, this being, as already described, overhung and shadowed by the dark-coloured roof. In endeavouring to reach the open air once more, they always fly against the ten bright streaks on the spathe, through which the light shines, and after many attempts usually only regain their freedom by chance, when, wearied out, they begin to creep slowly to the top of the spadix. This barrier is so effective that the plant may be carried about for some time without the escape of a single insect from the trap, though if it is cut open they fly quickly away through the slit.

When pollination has been effected, the projecting part of the spadix shrivels up, while the arched lobe of the spathe folds down and completely closes the entrance. The offensive odour disappears at the same time, the spathe assumes an inconspicuous pale-reddish colour, and finally falls off, together with the upper part of the spadix.

Visitors.—Knuth (Capri) observed minute flies and midges, small ants, and an earwig (Forficula decipiens *Géné*).

2915. A. proboscideum Savi.—Arcangeli (Nuovo Giorn. bot. ital., Firenze, xiii, 1895) states that this species is pollinated chiefly by fungus-midges (Mycetophilidae). The upper part of the spadix serves partly to prevent the escape of insects, and also partly, no doubt, as nourishment for them later.

941. Dracunculus Adans.

2916. D. vulgaris Schott (= Arum Dracunculus *L.*).—Delpino ('Ult. oss.,' p. 2380) states that the flowers of this South European species are visited and pollinated by flesh-flies.

In Italy, however, Arcangeli (Nuovo Giorn. bot. ital., Firenze, xv, 1883) observed carrion-beetles as the chief visitors; in five inflorescences there were 463 beetles, 377 of them belonging to the species Saprinus nitidulus *F.*; he therefore describes the plant as 'necrocoleopterophilous.' As in Arum italicum *Mill.*, four stages of anthesis may be distinguished:—

(1) The spathe opens, the anthers being closed; the stigmas are receptive and are pollinated by beetles, which hasten, covered with pollen, to the flowers, attracted by the smell of carrion.

(2) The stigmas fade; the anthers still remaining closed.

(3) The anthers dehisce at the beginning of the second day; the carrion-beetle visitors dust themselves again with pollen.

(4) The lower part of the spadix, hitherto smooth as a mirror, becomes wrinkled, so that the carrion-beetles can climb up on it, reach the open air, and then pollinate other flowers.

Delpino and Mattei (Malpighia, Genova, iii, 1889–90, p. 38) assert that flies (Calliphora vomitoria *L.*, Sarcophaga carnaria *L.*, Lucilia sp. and so forth) may actually be considered pollinators, so that the plant is sapromyophilous. They also state that only flies are found in the traps of plants growing sporadically in woods.

Smooth beetles, not very skilful in flying, would scarcely be capable of transferring the pollen of this apparently adynamandrous plant. The wild plants visited by flies are, according to these investigators, very fertile, while the garden plants or garden escapes visited almost exclusively by carrion-beetles, remain sterile. The presence (smell?) of carrion-beetles seems to be the reason that flies do not visit such plants. The beetles appear to be attracted more by the imprisoned flies than by the putrid smell, and to have accustomed themselves later to the species because they find booty here. (*Cf.* Ludwig's abstract in 'Bot. Centralbl.,' Cassel, xlvi, 1891, pp. 38–9.)

Arcangeli, on the contrary, asserts (Malpighia, Genova, iv, 1890, p. 492) that he has observed several cases of direct pollination by means of beetles. Vinassa (Atti Soc. tosc. sci. nat., Pisa, vii, 1891, p. 317) confirms this.

The maximum temperature in the spathe is reached about 2.30 p.m., when it is 27° C. (as against 24·6° C.) air temperature.

In a later investigation (Boll. Soc. bot. ital., Firenze, 1897, pp. 293–300) Arcangeli found the maximum temperature between 8–10 a.m., when it was 28° C. in the spathe. A second maximum was observed in the afternoon. The air temperature at these times varied between 20·5° C. and 21·8 C.

Of these insects imprisoned in the 'bridal chamber' (149, 21, 200) this time only a decreasingly small number were beetles; most of them were Diptera, particularly the following 3 species—1. Limosina simplicimana *Rond.*; 2. Borborus equinus *Fall.*; 3. Sphaerocera pusilla *Fall.*, upon which the transfer of pollen devolved, while the presence of some Braconids was of secondary importance. Arcangeli did not observe ripe fruits.

Visitors. *Vide supra.*—J. J. Walker (Gibraltar, Ent. Monthly Mag., London, xxv, 1888–9, p. 33) observed carrion-flies (Calliphora vomitoria *L.*, and Scatophaga sp.), and carrion-beetles (Creophilus maxillosus *L.*, Dermestes vulpinus *F.*, and 3 sp. of Saprinus).

2917. D. canariensis Kunth.—This species is self-fertile in the Pisa Botanic Garden; Arcangeli, however, says (Nuovo Giorn. bot. ital., Firenze, xv, 1883) that cross-pollination is not excluded. Fruit-devouring insects, probably carpophilous beetles (Cetonia, Oxythyrea, and others), may be considered pollinators, as an odour of pine-apple and melon is perceptible during anthesis.

942. Arisaema Mart.

E. Baroni (Nuovo Giorn. bot. ital., Firenze, New Ser., iv, 1897) describes extra-floral nectaries in some species of Aroideae belonging to this genus, which were indigenous to China and cultivated in the Florence Botanic Garden. Nectar-receptacles are here found in the angles of the individual leaf-segments, which are no doubt of importance in cross-pollination. These species possess, particularly at the ends of the leaf-segments, appendages resembling the end of the spathe. The insects creep easily in the direction of the appendage to the nectaries, while others, misled by the similarity of the structure, reach the spadix by creeping over the spathe to that point on its inner surface where it is touched by the former. They creep thence on the spadix into the 'bridal chamber,' where they deposit and collect pollen. (*Cf.* Solla's abstract in Bot. Centralbl., Cassel, Beiheft vii, 1897–8, pp. 99–100.)

2918. **A. filiforme** Blume.—The remarks made by Delpino in No. 2925 apply here also.

943. Helicodiceros Schott.

2919. **H. muscivorus** Engl.—Arcangeli states that this species is pollinated by flies (species of Somomyia and Calliphora): 378 insects (371 flies and 7 beetles) were observed in one inflorescence. In opposition to Schnetzler, Arcangeli is of

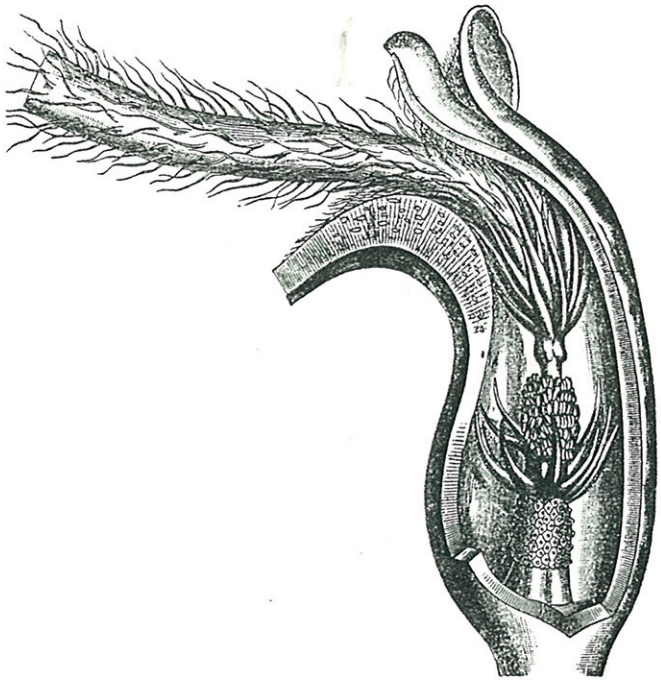

FIG. 412. *Helicodiceros muscivorus, Engl.* (after A. Engler). Lower part of spadix and spathe. The upper part of the former (not figured) resembles the lower part.

opinion that insects visiting the inflorescences only effect crossing, and do not serve as nourishment for the plant, as the necessary secretory organs are absent from the inflorescences, and the fly-larvae developing in it live for some time.

944. Sauromatum Schott.

2920. **S. guttatum** Schott.—Delpino (Malpighia, Genova, iv, 1890) states that the flower mechanism of this species resembles those of Arum italicum *Mill.* and A. maculatum *L.*

945. Amorphophallus Blume.

2921. **A. Rivieri** Dur.—Pirotta (Nuovo Giorn. bot. ital., Firenze, xxi, 1889, p. 156) says that a plant of this species cultivated in the Rome Botanic Garden is necrocoleopterophilous, for 122 carrion-beetles were once found in the inflorescence, these belonging to nine species and six genera: Saprinus nitidulus *F.* (65) was the most numerous, and S. aeneus *F.* (30) came next.

2922. **A. Titanum** Becc. (Beccari, Bull. R. soc. tosc. ort., Firenze, xiv,

1889.)—In this species, bearing 'the largest flower in the world,' there is a huge spathe in the form of a bright green funnel, white above, with a rich wine-red inner surface. The cream-yellow spadix, attaining a length of 1½ m., projects from this cup (1·20 cm. broad), its penetrating smell of flesh attracting swarms of flies in its native place, Sumatra. These enter the lower part of the spathe and effect pollination.

2923. A. campanulatus Blume (= Arum campanulatum *Roxb.*).—Delpino ('Ult. oss.,' p. 238) supposes that this East Indian species is pollinated by flesh-flies. Arcangeli (Nuovo Giorn. bot. ital., Firenze, xv, 1883) says that the visitors are almost exclusively carrion-loving beetles of the genera Saprinus, Dermestes, and Oxytelus.

2924. A. variabilis Blume.—Delpino (op. cit.) supposes this species to be pollinated by snails.

946. Typhonium Schott.

2925. T. cuspidatum Decne.—Delpino (op. cit.) supposes this species to be pollinated by snails, which are attracted by its pleasant odour, creep through a narrow opening to the female flowers, which are surrounded by the spathe and mature first. The snails will pollinate the stigmas if they come from inflorescences in the second stage with mature anthers. After pollination has been effected, the opening which leads to the female flowers closes, and the snails still present in the cavity are killed by a caustic (corrosive) liquid now secreted inside the spathe, being thus prevented from devouring the inflorescence.

947. Pinellia Tenore.

2926. P. tripartita Schott (= Atherurus tripartitus *Blume*).—As No. 2925.

948. Anthurium Schott.

Species of this genus agree with No. 2925.

2927. A. Pothos.—Delpino ('Altri appar. dicog. recent. oss.,' p. 62) describes this species as protogynous, with short-lived stigmas.

949. Alocasia Neck.

2928. A. odora C. Koch.—As No. 2925.

950. Ambrosinia L.

2929. A. Bassii L. (Delpino, 'Ult. oss.,' pp. 230–1.)—In flowers of this species the stigmas are situated outside at the end of the spadix, and the anthers inside the spathe, so that fly visitors must first touch the former and then the latter, thus always effecting cross-pollination.

951. Stylochiton Lepr.

2930. S. hypogeum Lepr., and **2931. S. lancifolius** Kotschy et Peyr.—Engler ('Pflanzenleben unter d. Erde') states that the inflorescences in these species, consisting of male and female flowers, are surrounded by a spathe and remain below the ground. Only the tip projects, and the insects effecting pollination creep down from this to the male and female flowers below.

952. Biarum Schot., and 953. Cryptocoryne Fisch.

The flower mechanisms of species belonging to these genera resemble that of Nos. 2930 and 2931.

954. Calla L.

Protogynous, hermaphrodite flowers, closely crowded on a fleshy spadix, with a shallow spathe.

2932. C. palustris L. (Herm. Müller, 'Weit. Beob.,' I, pp. 283–4; Warming, 'Smaa biol. o. morfol. Bidrag'; Engler u. Prantl, 'Araceae,' in 'D. nat. Pflanzenfam.,' II, 4; Knuth, Bot. Centralbl., Cassel, li, 1892, pp. 289–91, 'Beiträge,' I.)—The large, externally greenish spathe in this species surrounds the short-stalked inflorescence during the bud stage. When it unfolds it is about 3 cm. broad and 4 cm. long, and ends in a cornet-shaped tip almost a cm. long. This large, ovoid plate, white inside with a faint greenish tinge, serves as a 'sign-board.' The conspicuousness is still further increased by the short-stalked spadix, which is about 1·5 cm. long and 0·8 mm. in diameter. Herm. Müller describes the flowers as nauseous, on account of their disagreeable odour.

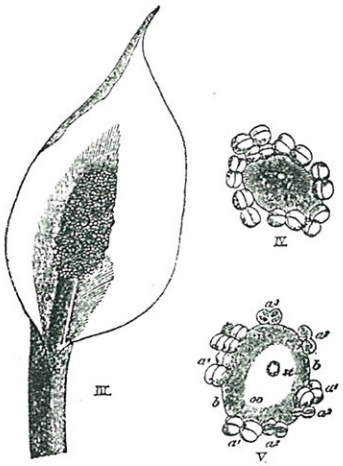

FIG. 413. *Calla palustris*, *L.* (after Herm. Müller). III. Inflorescence (× ⅔). IV. Single flower in the first (female) stage: the anthers are still closed, the ovary (*ov*) ends in an ovoid one, the truncated end of which forms the stigma (*st*); this is now fresh, greenish in colour, and receptive. V. Single flower in the second (male) stage: the stigma (*st*) has become brown; the anthers are partly closed (a^1), partly dehisced and covered with pollen (a^2), while one (a^3) is already empty; the ovary has swollen so much that at *b b* it has become feathered by pressing against the ovaries of adjacent flowers. (× 5.)

The flowers are markedly protogynous. The 30–50 stigmas appear in the first stage of anthesis as small, whitish circles, strongly papillose and viscous, on the ovaries. Those of the lower ones are receptive immediately after the opening of the spathe. The anthers only dehisce when some stigmas have shrivelled. In the first stage they are sessile; in the second they develop short stalks, so that they are raised to the level of the stigmas. Engler points out that the anthers dehisce quite without order, those of flowers situated above and below dehiscing simultaneously, while the stigmas always mature from below upwards, and in such a manner that the stigmas of the uppermost flowers and those facing the spathe can be self-pollinated, while the lowest are limited to cross-pollination.

VISITORS.—The following were recorded as stated.—

Knuth, a few small flies: also (4. 8. '97, in the Kiel Oberrealschule Garden) a young individual of Helix hortensis *L.*, creeping over the inflorescence. Examination of its foot showed the presence of pollen-grains, and demonstrated the possibility of malacophily in this species. Herm. Müller, numerous small Diptera, e. g. Drosophila graminum *Fall.*, Hydrella griseola *Fall.*, and species of Chironomus and Tachydromia; also, as casual visitors, a few small beetles—Cassida nobilis *L.*, Aphthona caerulea *Payk.*, Meligethes sp., Hypera polygoni *L.*, and Sitona sp. Warming mentions snails

as occasional visitors; they creep over the crowded anthers and stigmas forming a continuous surface, and easily transfer pollen to the latter.

955. Acorus L.

Protogynous, sessile, hermaphrodite flowers, arranged on a spheroido-cylindrical spadix.

2933. A. Calamus L. (Kerner, 'Nat. Hist. Pl.,' Eng. Ed. 1, II, p. 402; Ludwig, 'Zur Biol. d. phanerog. Süsswasserflora,' p. 128; Knuth, 'Bl. u. Insekt. a. d. nordfr. Ins.,' pp. 139–40.)—The spadix of this species, up to 10 cm. long and $1\frac{1}{2}$ cm. thick, is completely covered by several hundred (700–800) closely-crowded flowers, each possessing a sessile, punctiform stigma and six stamens, 12 mm. long. Formation of the berry-like fruits has never been observed in Europe, though they set in Japan and India. Ludwig ascribes this to the circumstance that all European Calamus plants are supposed to have been derived from a single stock, introduced by Clusius. According to this, the species is adynamandrous.

This attempted explanation seems to me more probable than the one given by Kerner, who says that the species of Calamus set no fruit in Europe because the insects which pollinate them are absent. Autogamy is completely excluded by marked protogyny; and Kerner says that geitonogamy cannot take place automatically by fall of pollen, this being adherent, but can only be effected by the help of insects. Judging from the construction of the spadix, all our native Diptera and Hymenoptera would be able to transfer pollen; but insect-visits have not yet been observed in Europe. Warnstorf describes the pollen-grains as yellowish in colour, very small, ellipsoidal to oval, glabrous; about 12 μ broad and 18–22 μ long. (*Cf.* Loew, 'Blütenbiol. Floristik,' p. 363.)

CXXI. ORDER *LEMNACEAE* LINK.

956. Lemna L.

LITERATURE.—Ludwig, 'Süsswasserflora,' pp. 38–40; Trelease, Proc. Soc. Nat. Hist., Boston (Mass.), xxi, 1882, pp. 410–15; Hegelmaier, 'Lemnaceae,' in Engler u. Prantl's 'D. nat. Pflanzenfam.,' II, 3; Delpino, Riv. bot. dell' anno 1880; Knuth, 'Bl. u. Insekt. a. d. nordfr. Ins.,' p. 138; Warming, Verh. bot. Ver., xxxviii, 1896.

2934. L. arrhiza L. (= Wolffia Michelii *Schleid.*); **2935. L. trisulca** L.; **2936. L. minor** L.; and **2937. L. gibba** L.—Hermaphrodite or monoecious species, seldom flowering in Germany. Propagation is therefore almost exclusively effected by the sprouting of the thalloid, usually lens-shaped, floating stem. L. arrhiza does not flower at all in Germany, but only in warmer regions. The accounts of the flower mechanism given by different investigators are contradictory in part, but may, in Ludwig's opinion, all be correct, as the mechanism of the same plant may vary in different regions.

As I have never had an opportunity of observing species of Lemna in flower, I will give Ludwig's description of the oecology of L. minor, as he observed them in a room, and in a sheltered pond in the neighbourhood of Greiz from May to July. The monoecious inflorescence consists either of one short-styled pistil above and two

stamens situated at a lower level, and upwardly directed like it, or pistil and stamens, surrounded by an irregularly torn involucre, all situated on different parts of the thallome.

The two stamens mature successively, considerably earlier than the stigma. Automatic self-pollination is excluded by this protandry, and also by the relative position of stigma and anthers. It is incredible that the wind plays a part in pollination, on account of the shortness and stiffness of the stamens and the small quantity of pollen. In spite of its entire lack of attractions Ludwig considers the flowers entomophilous, and to be visited by insects which play on the surface of the water, particularly the gregarious water-measurers (species of Hydrometra), which propel themselves by fits and starts with a rowing movement. The structure of the pollen-grains favours the theory of entomophily, for they are prickly and beset with numerous processes. The diameter of a pollen-grain is 26 μ and the length of its spines about one μ. The grains cling easily therefore to the bodies of insects brushing over the anthers, and can be conveyed by them to the somewhat concave stigmatic disk. Insects playing on or between the Lemna clumps at once touch both anthers and stigma, so that the plant needs no special means of attraction and no equivalent reward (perhaps the offering of a firm substratum may be considered as such). Species of Lemna therefore attain what ordinary 'flowers' gain by the development of bright colouring, nectar, and fragrance.

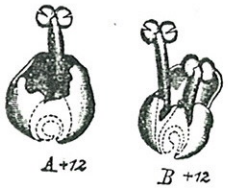

FIG. 414. *Lemna trisulca*, L (after A. Engler). Inflorescence in two successive stages.

Trelease found the plant protogynous. He thinks that the Lemna clumps are crowded together by currents of water and wind in order that the little plants in the female stage may easily come into contact with those in the male stage, and pollination be thus effected. He also says that self-pollination is not excluded in the plants observed by him, as one stamen matures three days later than the stigma, and the latter is then still receptive; the second stamen dehisces after three days more.

Hegelmaier also describes L. minor as protogynous; but the stigma is still receptive when the anthers dehisce, so that automatic self-pollination takes place, while crossing is improbable.

Delpino agrees with Ludwig's explanation of the mechanism; he supposes that water snails must also be considered as pollinators.

Kalberlan (Zs. Natw., Stuttgart, lxviii, 1894, pp. 136–8) describes Lemna as protogynous and probably pollinated by insects.

L. Vuyck (Bot. Jaarb. Dodonaea, Ghent, vii, 1895, p. 72) found flowering plants of Lemna in Holland in the summer of 1894. These were always protogynous-dioecious. The inflorescences agreed exactly with the description given by Hegelmaier, but Vuyck found that the funnel-shaped stigma secretes a fluid containing a great deal of sugar, so that it acts as a nectary. The division of labour is not very far advanced in this small, simply-constructed plant, for here one organ serves purposes divided among several in other flowers.

According to this the flower, or rather the inflorescence, is entomophilous; but Vuyck observed no insect-visits. The fact that the pollen-grains are beset with