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Flower Ecology

LOUIS BY
L. H. PAMMEL.

Press of J. B. Hungerford.

This book is dedicated to my parents, as an appreciation for what they have done for me.

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WORKS OF REFERENCE.

Sprengel—Das entdeckte geheimniss, der natur im bau und der befruchtung der blumen. Berlin, 1793.

Gray - structural botany, p. 215.

MacLeod—Lijst von Boeken, Verhandeligen, enz omtrent de bevruchting der bloemen, von 1883 to 1889 verschenen. Botanisch Jaarboek, tweeds jaargang 1890. Kruidkundig genootschapte Dodonaea te Gent.

H. Mueller—Die befruchtung der blumen durch insekten. Leipzig, 1873. English translation by D'arcy W. Thompson, London. 1883. Die alpenblumen, ihre befruchtung durch insekten, und ihre anpassung an dieselben. Leipzig, 1881, etc., etc.

Fritz Mueller—Flowers and insects. Nature, Vol. XVII, p. 78, 1878. Two kinds of stamens with different function in the same flower. Nature, Vol. XXVII, p. 364, 1883, etc., etc.

Axell—Om anordningarna for fanerogama vaxternas befruktning, Stockholm. 1869, etc., etc.

Hildebrand—Ueber die befruchtung der salbeiarten durch insekten. Bonn, Sitzber. Niederrheimgesellsch, pp 54-56, 1864.

On the impregnation of orchids as a proof of the two different effects of pollen. Ann. and Magazine of Nat. Hist., Series 3, Vol. XII, pp. 169-174, 1863.

Die geschlechter vertheilung bei den pflanzen. pp. 92. Leipzig, 1867.

John Lubbock—On British wild flowers considered in relation to insects. London, 1875.

Scientific lectures (Lecture I, flowers and insects). London, 1879.

Grant Allen—The colors of flowers as illustrated by the British flora Nature, Vol. XXVI, pp. 299, 323, 346, 371. London, 1882.

Delpino—Ulteriori osservazioni sulla dichogamia nel regno vegetable Milan. Part I, 1868, 1869; Part II fasc. I, 1870; fasc. II, 1875.

A. Kerner—Die schuetzmittel der bluethen gegen unberufene gaeste. Vienna, 1876. Translated by Dr. Wm. Ogle, "flowers and their unbidden guests." London, 1878.

Pflanzenleben. Vol. II, p. 91-447. Engl. Translation, Oliver Natural History of Plants.

Forbes—Selective discrimination of insects. Nature, Vol. XVII, p. 62, 1878.

Bennett—Insects and Flowers. Popular Science Review, Vol. XIV, pp. 113-125, 1875.

Francis Darwin—Bees visiting flowers, papilionaceae. Nature, Vol. IX, p. 189, 1874.

Alpine flowers, a review of Hermann Mueller's alpenblumen. Nature, Vol. XXIII, p. 333, 1881.

Charles Darwin—Fertilization of orchids. London, 1862.

The effects of cross and self-fertilization in the vegetable kingdom. London, 1876.

The different forms of flowers on plants of the same species, etc.

Loew—Beitraege zur Kenntniss der Bestäubungs einrichtungen einiger labiaten with two Plates. Ber. d. deut. bot. Gesellsch. Berlin, Vol. IV, 1896, pp. 113-143, plates V and VI, etc.

Zur Biologie der Apocynen Bot. Centralblatt, Vol. VII, No. 45, 1881.

Ueber die biologischen eigenthümlichkeiten der plantagineen. Bot. Centralblatt, No. 39, 1880, etc.; Pflanzenbiologie.

Asa Gray—Structural botany, New York and Chicago, 1879.

How plants behave, New York, 1872.

Cleistogamous flowers in *exybaphus nyctaginea*. Am. Naturalist. Vol. VII, p. 692, 1873

Cross-fertilization of *scrophularia nodosa*. Journal of Botany, Vol. IX, p. 375, 1871, etc.

W. Trelease—Nectar, what it is and some of its uses. Report upon cotton insects. By Henry Comstock, Washington, 1879.

On the structure which favors cross-fertilization in several plants. Proceedings Boston Soc. of Nat. Hist., Vol. XXI, 1882, Mch. 15.

The nectary of yucca. Bull. Torrey Bot. Club, New York, 1886, p. 135, Rep Mo Bot. Garden, etc.

Charles Robertson—Note on the mode of pollination of *asclepias*. Bot. Gazette Vol. XII, 1887, p. 288.

Flowers and insects. Bot. Gazette Vol. XIV, p. 120, etc. Am. Nat. Vol. XXIX, p. 97.

Trans. Acad. of Sci. St. Louis, Vol. VI, No 14, etc., etc.

C. V. Riley Observations on the fertilization of yucca and on the structural and anatomical peculiarities in *pronuba* and *prodaxus*. Am. Naturalists, Vol. XVII, 1883, p. 197.

On the oviposition of the yucca moth. Transaction of St Louis Acad. of Sci., St Louis, Vol. III, No. 2, p. 208. See also Vol. III, p. 568, etc. Rep. Missouri Bot. Garden, 1892.

Foerste—The fertilization of the wild bean (*phaseolus diversifolius*). Am. Naturalist, Vol. XIX, p. 887. 1885. Notes on structure adapted to cross-fertilization with plate. Bot. Gazette, Vol. XIII, 1881, p. 151. The nectar glands of *apios tuberosa*. Bull. Torrey Bot. Club, Vol XI, p. 123, 1884, etc. Sensitive stigmas as an aid to the cross-fertilization of flowers. Proc. Am. Ass. Adv. of Sci. (Buffalo) 1876, p. 286, etc.

C. M. Weed—Ten New England blossoms and their insect visitors.

PREFACE.

It has always seemed desirable to me to give some instruction along ecological lines in a general course in botany. Ecology considers the external relations of plants, and no field offers greater opportunities to awaken an interest in botany than the relations existing between flowers and insects and other agents in bringing about pollination.

Much of the material contained in the following pages has appeared before in some lectures delivered at the meetings of the horticultural societies of this state. I have however added considerable new material. I have made free use of published papers on the subject, especially those of Robertson, Mueller, Ludwig, Trelease, Gray, Riley, Bailey, Kerner and others, full credit has been given in the proper places. I am also under obligations to Mr. C. R. Ball who has assisted me in various ways as well as Mr. Combs; Mr. E. D. Ball who made some of the insects determinations for me, and some help from Prof. H. Osborn and Mr. W. Newell. To all I wish to express my sincere thanks.

CHAPTER I.

FLOWER ECOLOGY.

Few questions have attracted greater and more attention than the adaption to secure cross fertilization. Aside from the interest scientists take in this question, it has a practical bearing on horticultural and agricultural problems. When we remember that horticulturists are turning their attention to the improvement of our native fruits by cross fertilization and hybridization, we must accord to this subject a prominent place.

Insects have played a very important part in rendering flowers attractive. It is well known that many plants cannot produce seed unless an insect or some other agent conveys the pollen from anther to stigma.

History. It is interesting to follow the history of this phase of botany. It is now one hundred years since the foundation of this study was laid. The keen and sharp observer, Christian Conrad Sprengel, published a remarkable book on the structure of flowers and their relation to insects, although he made some observations as early as 1787. In speaking of the hairs on the corolla of a *Geranium* he says: "The wise Author of Nature would not have created even a hair in vain." Earlier than this Koelreuter saw the necessity of insect visitors to some flowers. Sprengel surmised that these hairs served to protect the honey from rain. This work was almost lost sight of till the brilliant mind of Darwin saw the full import of Sprengel's

gel's observations. Darwin's work "On the Fertilization of Orchids," published in 1862, gave an impetus to the study which has continued till the present time. D'Aarcy W. Thompson in 1883 gives the titles of 814 papers; J. MacLeod, 638 papers from 1883 to 1890.

Among the numerous workers in this line I can only mention a few: Hermann Mueller, Fritz Mueller, Axell, Hildebrand, Lubbock, Grant Allen, Delpino, Kerner, von Marilaun, Forbes, Bennett, Darwin, Loew and Ludwig. In our own country: Gray, Trelease, Riley, Foerste and Beal, Weed. The work of Mr. Charles Robertson, of Carl-ville, Illinois, deserves special mention. He has done an enormous amount of careful and conscientious work. No other American botanist has collected such valuable data. Those interested in this subject should consult these papers.

**Pollination and
Fertilization.**

At the out set it is well to have a clear understanding of what is meant by pollination and fertilization. Pollination is simply the conveying of pollen from the anther to the stigma. Fertilization occurs after the pollen has reached the stigma; it is the impregnation of the ovule. Fertilization has been defined as the union of protoplasm of two different cells.

**Adaptations for
Sexual Reproduction.**

In most higher plants both kinds of organs occur in the same flower, so that it is possible to have close fertilization—autogamous;—or from flower to flower in the same plant—geitonogamous. But the rule is to be cross-fertilized—xenogamous.

**Conditions opposed
To Self Fertilization.**

DIOECIOUS. Stamens and pistils occur on different individuals, as in willow.

TRIOECIOUS. Staminate, pistillate, and hermaphrodite flowers on different branches, as in ash.

MONOECIOUS. Staminate and pistillate flowers separated but on the same plant, as in corn, melon, oak, etc.

FIG 1.

Fig. 1. Eel grass (*Vallisneria spiralis*);—a. pistillate flower; b. male flower; c. floating staminate flowers with pollen. (After Lubbock).

GYNODIOECIOUS. Some plants produce hermaphrodite flowers, others only pistils without stamens, as in thyme.

ANDROMONOECIOUS. Some plants produce hermaphro-

dite flowers, others only stamens, as in buckeye.

DICHOGAMOUS. Stamens and pistils mature at different times.

Proterandrous: Stamens mature before pistil, as in sunflower:-

Proterogynous: Pistil matures before stamens, as in Plantain.

Heterodichogamous: Occurrence of two kinds of plants of the same species—some proterandrous, others proterogynous.

FIG. 2.

Fig. 2. Flowers of *Vallisneria spiralis* on the surface of the water. The floating staminate flowers; one has come in contact with the stigmas. (After Kerner von Marilaun).

DIPTOPOGAMOUS. Stamens and pistils in the same plant but at different heights. Stamens on other individuals corresponding in heights to pistils and vice versa:

Heterodistylous: Occurrence of two kinds of plants, some plants having long stamens and a short style and others having short stamens and a long style, as in primrose.

Heterotristylous: Some plants having a long style and stamens of both short and of medium length in the same flower; a second kind having long stamens and stamens of medium length and a short style; a third plant has short and long stamens and a pistil of medium length corresponding to those of medium length stamens, as in oxalis, lythrum, etc.

AUTARIGYNOUS. Self sterile plants. The pollen of a flower or of a plant will not fertilize the ovule of that plant. Cases numerous, clover, calamus, etc.

Self Fertilization **CLEISTOGAMOUS.** Flowers do not open
In Plants. as in the flowers of some Violets, Dead
Nettle and some grasses.

X Methods of Bringing Delpino has made two divisions:
Fertilizing Bodies Together. (1.) **ZOOGAMOUS**, in which
fertilizing bodies move of their own accord. In lower
plants, algae, some fungi, etc.

I. **DIAMESOGAMOUS**, in which movement is brought about by some foreign agent. We are concerned here with those of our second division. The agents may be arranged as follows:

1. **HYDROPHILOUS.** Pollination is brought about by the water.

2. **ANEMOPHILOUS.** Wind is the agent.

3. **ZOIDIOPHILOUS.** Pollination is brought about by animals.

a. **ORNITHOPHILOUS.** Pollination is brought about by birds that look for insects or nectar.

b. **ENTOMOPHILOUS.** Pollination brought about by insects.

1. **MELITTOPHILOUS.** large bees.

2. MICROMELITTOPHILOUS, small bees and other insects.
3. MIOPHILOUS, flies (Diptera).
4. MICROMIOPHILOUS, small diptera.
5. SAPROMYOPHILOUS, carrion flies.
6. CANTHAROPHILOUS, beetles, (Cleopectera).
7. PSYCOPHILOUS, butterflies, (Lepidoptera).
8. SPINGOPHILOUS, moths and sphin.
- c. MALACOPHILOUS. Snails,

CHAPTER II.

HYDROPHILOUS.

Few flowers are pollinated by water.

Eel Grass *Vallisneria spiralis* is an excellent illustration.

It is a common plant found in ponds and slow running streams in many parts of the eastern United States. It is stemless, bearing linear, thin, ribbon-like leaves. The flowers are dioecious. The

FIG. 3.

Fig. 3. Duckweed (*Lemna minor*). 1, plant with only one pistil mature; 2, the same with the first stamen mature; 3, both stamens mature, magnified six times; 4, a fully developed flower magnified twenty-five times. (After Trelease.)

pistillate flowers are solitary and borne on long, slender threads, which bring it to the surface of the water. The flower consists of a perianth composed of three petals and three small sepals. The three large stigmas are two-lobed and are so situated in the mature flowers that they turn back beyond the three petals; hence it is important that the sepals should be small. The staminate flowers are numerous and

crowded in a head at the bottom. When nearly mature the staminate flowers break away from the plant and come to the surface of the water, on which they float. In this condition it forms a ball, but when fully mature the petals turn back, forming a skiff like arrangement, the stamens lengthen out and the anther cells open. Each anther contains thirty eight large, more or less viscid, pollen grains. The three skiff like sepals are admirably adapted to float on water. Short waves or currents of wind drive them along until they come against a solid object, where they remain, and if it be a pistillate flower the stamens come in contact with it, leaving the pollen attached to the stigmas. After fertilization the threads that bear the fertile flowers coil up spirally, drawing the fruit under water, to ripen.

LEMNA. Species of duckweeds are admirably adapted to water pollination. The following account of pollination of *Lema minor* is based on the observations made by Trelease. Duckweeds are among the smallest of flowering plants and form scums on the surface of ponds and slow running streams in summer. They are very simple in their structure. Each fertile frond produces a single flower from a cleft in the margin. The flower consists of a single pistil and two stamens and a subtending bract. When the flower expands, the pistil elongates sufficiently to expose about half its length beyond the tips of the marginal fissure of the frond. The stigma becomes moist by the exudation of a fluid; and is now receptive. In this condition it remains some days when the stamen furthest from the base of the frond becomes exerted, attaining the length of the pistil when it dehisces, the pollen remaining heaped in the open cells of the anther. The second stamen dehisces several days later. The flowers are therefore strongly proterogyn-

ous. "Surface currents due to the wind or other causes crowd the plantlets together in masses in which the relations of the several individuals are incessantly changing." The receptive stigmas must be pushed against the older anthers, through which they are pollinated. While there is in this case an admirable adaptation for cross pollination, self-fertilization may result when the pollen of the older stamen drops on the stigma.

FIG. 4.

Fig. 4. (*Potamogeton crispus*)—Staminate flowers with debisceling anthers shown on the left. Pistillate flowers with large viscid stigmas on the right. (After Kerner von Marilaum.)

Another interesting plant pollinated by
Water Weed. water is *Elodea canadensis* commonly found

in slow running streams and ponds northern United States.

Fig. 4 (Indian Corn, *Zea mays*.)—A pistillate spike. B, pistillate flowers with envelopes. J, same showing long silken thread. B-o, Staminate flowers with loosely hanging stamens (from Hackel.)

It has also attracted considerable attention in Europe from the fact that it has become a veritable nuisance in choking canals and streams. The plant bears three kinds of flowers: Staminate, hermaphrodite and pistillate. But all of these forms apparently never appear together. Staminate and pistillate occurring together. The fertile flowers are born on a long tube which in most cases comes to the surface of the water where it expands. The staminate flowers are attached at the bottom; they break off as in *Vallisneria*, come to the surface and float on the water. When fully mature they expand and shed their pollen around the stigmas. Several other plants especially the Asiatic *Vallisneria alternifolia* and the tropical African *Lagarosiphon* are pollinated in a similar way.

CHAPTER III.

ANEMOPHILOUS. *wind*

The flowers in this class are usually dull in color, contain no nectar; the sexes are often separated, *i. e.*, they occur in different flowers, one flower staminate, the other pistillate. Both kinds of flowers are either on the same plant, when they are said to be monoecious, or when one plant bears either staminate or pistillate flowers it is said to be dioecious. In wind pollinated flowers the anthers are borne in such a way that the slightest breeze will cause the pollen to be shaken out. The anthers always contain an abundance of pollen. The pollen grains are light, not viscid, and easily carried by the wind.

Grasses. These important plants, numerous in species, are almost exclusively pollinated by the wind. The flowers are usually hermaphrodite, some monoecious and some dioecious. In quite a number there is a difference in the time of maturing of stamens and pistil.

Lodicules. Many of the flowers of grasses have a pair of small scales (lodicules). They are close together, and the bases are somewhat grown together. Hackel says. "The rapid swelling of the bases, at least, causes the separation of the flowering glume and palea, and consequently the opening of the flower." In grasses where these scales swell but little, the flowers do not open very far. When they are absent the spikelets are closed at the sides and the stamens and pistil only protrude at the apex. These scales are very turgid at the time of flowering.

Time of Opening of Flowers. It is well known that temperature and moisture greatly influence the opening of flowers. Rains and low temperature may retard the opening

FIG. 5.

Fig. 5. Tall meadow oat grass, (*Arrhenatherum elatius*). Wind pollinated, showing how anthers open and the long plumose stigmas protruded. 1, Closed anther. 2, An opened anther. 3, Parts of the pistil separated. 4, The effect wind has on the flowers. (After Kerner von Marilaun.)

not only hours, but days. Dry air and a high temperature also retards opening. The flowers of grasses open early in

Fig. 6. Filbert (*Corylus avellana*) showing fruits to the left and large staminate catkins and the short axillary branches with pistillate flowers to the right. The stigmas are red. (After Kerner von Marilaun).

the morning, usually when there is some dew on the grass. Mr. F. A. Sirrine found about Ames that flowers usually open between 5 and 9 a. m.

The flowers of *Festuca elatior* open before 7 a. m., *Andropogon provincialis* before 7 a. m. Some, however, open between 5 and 7 p. m. Kerner Marilaun states 4 to 5 a. m. for *Poa* and *Koeleria*, 5 to 6 a. m. for *Briza media* and wheat (*Triticum*), 7 to 8 a. m. for oats (*Avena*) and timothy (*Phleum*), 11 a. m. *Agrostis*, 4 p. m. *Agropyron* *Holcus* opens its flowers twice during the day—at 6 a. m. and 7 p. m.

Corn. As a rule the flowers of corn are found in separate parts of the plant; the staminate spikelets, collectively called the tassel, are at the extremity, the pistillate flowers in the axils of the leaves; the sexes are therefore separated (monoecious). Each staminate flower contains three stamens. When ripe they hang loosely from the flower. Each kernel (ovule) has coming from it a long silken thread which is hairy, and when ripe somewhat viscid. The pollen shakes out easily, as every one knows who has walked through a cornfield and found pollen on his clothes. The flowers are proterogynous.

The flowers of corn develop a certain amount of odor, which is plainly perceptible at some distance. The flowers are frequently visited by honey bees and other insects, chiefly in quest of pollen.

Wheat. In wheat the anthers and stigmas mature at the same time, but the flowers are only partially opened for about fifteen minutes. When the flowers open the pollen is scattered, some of which remains within the flower. Cross-pollination is brought about by the wind. Delpino states that the flowers may be self-fertilized and good seed produced.

Fig. 7. Dwarf Mountain Pine (*Pinus pumilio*).—1 Staminate flower. 2 Section through three staminate flowers. 3 Two staminate catkins more magnified. 4 Branch containing staminate flowers from which the pollen has fallen, and a pistillate cone on the right hand branch. 5 pistillate flowers. (After Kerner von Marilsun.

Tall Meadow Oat-Grass. The versatile anthers are borne on long filaments and are set in motion by the slightest breeze, which causes the pollen to be shaken out in clouds. The stigmas are long and plumose and readily catch the pollen. As in corn, the flowers are proterogynous and by the time pollen is mature the stigmas are withered.

Woody Plants. A large number of our woody plants are pollinated by the wind—the hazel, birch, pine, cottonwood, oak, elm, etc.

Hazel. In our own Hazel (*Corylus Americana* Walt.) the staminate catkins are pendent, the pistils occur in short erect cones quite inconspicuous, the stigmas are red. A great abundance of pollen is produced. Our Hazel flowers in early April. In the European hazel nut (*Corylus avellana*) the staminate flowers are borne in drooping cylindrical catkins, each flower containing eight stamens with short filaments. The anthers contain an abundance of pollen. The pistillate flowers are not conspicuous, several occurring in a scaly bud. The stigmas are of reddish color and large. Many wind pollinated flowers have red stigmas but these are to be explained on physiological grounds. The flowers may be proterandrous or proterogynous. As a general rule, in wind pollinated trees bloom before the leaves are out, because the leaves interfere with the distribution of pollen. As Robertson says: "In the case of the wind pollinated trees it is obvious that if the leaves were developed before the flowers, the process of pollination would be greatly impeded by the leaves interfering with the free circulation of the wind and catching the pollen which is intended for the stigmas."

Pine. The staminate flowers occur at the base of the shoot of the same sprig. The fertile catkins occur below the terminal bud or on the lateral young shoots. The

FIG. 9.

Fig. 9. (Pollen grains) 1 *Cobaea scandens*. 2 *Morinia persica*. 3 *Cucurbita pepo*. 4 *Passiflora kermesina*. 5 *Circaea alpinu*. 6 *Convolvulus sepium*. 7 *Cannabis sativa*. 8 *Pinus pumilio*. 9 *Mimulus moschatus*. 10 *Albucca minor*, round grains moistened, the others dry. 11 *Dianthus Carthusianorum*. 12 *Corydalis lutea*. 13 *Gentiana rhaetica*. 14 *Salvia glutinosa*. (After Kerner von Marilaun.

stamens open outwardly. The slightest jar on a tree will cause a shower of pollen to issue. The structure of the pol-

len grains is such that it is easily carried by the wind. It consists of three cells, one of which only is fertile. The others serve to buoy the pollen and therefore make it of easy transport. The pistillate flowers are colored red, and have a large receptive surface.

Pollen of conifers has been carried for more than a hundred miles. The so-called "showers of sulphur" on ponds consist of pollen grains which were suspended in the air and brought down during a shower of rain.

Alder. The alder, which is a common plant in Eastern States and Northeastern Iowa, bears its staminate flowers in long festoons. The pistillate catkins are more or less erect.

FIG. 10.

Fig. 10. 1-2 *Rhododendron hirsutum*, 4 *Epilobium angustifolium*. (After Kerner von Marilaun.)

Usually self-pollination is not prevented in the cultivated European species, nor in some of our wild species. John H. Lovell states the *Alnus incana* is partially dioecious. Honey bees occasionally visit the staminate flowers for pollen.

Aquatic Plants. Aquatic plants are also pollinated by the wind, as *Potamogeton crispus* L., a plant growing in ponds and slow running streams. While its leaves are immersed in water the flowers are produced above. The reddish brown stigmas mature before the anthers of the same flower are open, but when the stigmas are wilting then the perianth of the flower opens, the anthers mature, when the wind blows over the water it carries the pollen with it. Some of it is wasted, but a part of it is almost certain to come in contact with the stigmas of younger flowers.

Herbaceous Plants. Plantain: Common plantain occurs in all of our door yards and who has not observed the long, slender spike. The flowers are protogynous, the slender style shows before the stamens, when the stamens appear the style is withered. The pollen must therefore move upward. Anemophilous herbaceous plants occur in widely separated orders, as Meadow Rue (*Ranunculaceae*), Ragweed (*Compositae*), Hemp (*Urticaceae*), etc.

CHAPTER IV.

ENTOMOPHILOUS.

Anton Kerner, in that delightfully written work on the Natural History of Plants, says, "If, however, mere casual observation of the relation between flowers and their insect visitors is sufficient to cause aesthetic pleasure, and has stimulated people of every age and nationality to the production of works of art, it may be imagined how great must be the incentive to scientific study supplied by a deeper insight into these phenomena, and what extreme pleasure is derived from the successful discovery of the reasons for these wonderful relations, and from tracing their connection with other facts of science."

[Zoologists believe that the bodies of insects are developed for the special purpose of visiting certain flowers. It is equally true that flowers are correlated with the shape and habits of insects that visit these flowers. These insects vary from the small thrips, scarcely more than 1 mm. long, to our largest butterflies and the still larger ones of the tropics, whose expanded wings measure 15 cm. across. As such differences occur in the insect world, so too there is a great diversity among the flowers in odor and color. Beginning with the early spring flowers to those of late autumn there is a constant connection with the varied forms of insect life.]

In order to fully understand the wonderful adaptations between insects and flowers it will be necessary to consider the structure of certain parts of insects. Insects have been divided up into several orders. In point of importance they

may be arranged as follows: *Hymenoptera* *Lepidoptera*, *Diptera*, *Coleoptera*, *Hemiptera*, *Orthoptera* and *Neuroptera*. In pollination the last three may be excluded.

[The most important pollinators in the order *Hymenoptera* are honey-bees, bumble-bees, wasps, *Halictus*, *Andrena* and *Anthophora*. The mouth parts of bees are especially con-

FIG. 11.

Fig. 11.—Left hand figure, head of *Bombus agrorum* ♀ with mouth parts separated, magnified five times. Right hand figure that of hive-bee in the same position seen from below, magnified twelve times; *pl* labial palpi modified into a tongue sheath, *y* submentum (fulcrum,) *zz*, retractors, i. e. those chitinous pieces which unite the submentum with the ends of the cardines, and as they revolve backwards round the ends of the cardines, retract the mentum and its appendages, *li* ligula, *pm* maxillary palpi, *md* mandibles, *o* eyes, *lbr* labrum, *la* lamina. (After Hermann Mueller.)

structed for the purpose of collecting nectar. The mouth

parts of an insect consist of an upper lip, an under lip, a pair of anterior jaws or mandibles, and a pair of maxillæ. The lower lip and maxillæ are each provided with a pair of feelers or palpi. The mandibles are usually hard and horny, while the maxillæ are delicate and membranous. Different insects show great variation in the structure of their mouth parts, even in the same order. Take members of the genus *Prosopis* which construct their cells in sand and dry sticks, the lower lip is constructed in the form of a trowel. This insect has in fact no special adaptation for collecting nectar. Although these bees feed their young on honey and pollen, they can only obtain nectar in flowers with shallow nectaries. In different bees there are various gradations, as in *Andrena*, *Halictus* and *Chelostoma*. The lower lip becomes variously elongated until it reaches the length and form found in hive-bees and bumble-bees which enables them to extract honey from irregular flowers with deep seated nectar.

In *Bombus* the mouth parts consist of *pa*, the paraglossa, *li*, the ligula, *pl*, labial palpi, *pm*, maxillary palpi, *la*, lamina, *mt*, mentum, *st*, stipes, *md*, mandibles, and *o*, eyes. When the mouth parts are fully extended and separated it seems hardly possible that this large and complex apparatus for sucking, exceeding in length that of the head, can be received in the cavity below the head, but such is the case. When a bee is sucking honey just within its reach, the cardines, the chitinous retractors just at the base of the mentum, the laminæ, labial palpi and tongue are fully extended. As soon as the whorls of hairs at the point of the tongue are wet with honey, the bee by rotating the retractors (below the submentum) draws back the mentum and with it the tongue, so far that the laminæ now reach as far forward as the labial palpi. The laminæ and labial palpi now lie close upon the

tongue, overlapping at their edge form a tube, of which only a small portion protrudes. At the same time the bee draws back the basal part of its tongue into the hollow end of the

FIG. 11 A.

Fig. 11 A. Hind legs of bees, showing structures for collecting pollen, beginning from the left. Hairy bee (*Anthophora retusa*) four times enlarged. Bumble bee (*Bombus terrestris*) four times enlarged. Honey bee (*Apis mellifica*) five times enlarged. r trochanter. s femur. t tibia. a prickles on tibia. p tarsus (pollenbrush). f other segments of the foot. k claws. (After Behrens.)

mentum and so draws the tip of the tongue moist with honey into the tube where the honey is sucked in by the sucking stomach. In flowers with shallow nectaries the bee need not rotate the retractors. The tongue is therefore constantly encased by the laminæ and labial palpi.

When a bee flies from one flower to another it carries the proboscis extended so as to introduce it, in the act of alighting, into the tube of the flower. The tongue is, however, concealed within its sheath, to protect the delicate whorls of hairs. Bees also have certain parts specialized for the collection of pollen. In some bees this is collected on the lower posterior surface of the body; in others it is collected on the

legs.) In *Megachile*, where it is collected on the ventral surface, "the abdomen is furnished with long, stiff retroverted hairs, by means of which the pollen is brushed from the anthers as the insect passes in or out of the flower." The pollen grains are afterwards dislodged by means of its legs. These insects can therefore readily get the pollen from flowers with flat corollas. In *Anthophora* the pollen is collected by the *tibia* and *tarsus*. They are broad and flat and thickly covered with hairs. The pollen is brushed from the anther by means of the hairs on the tarsus, and later is transferred to the tibia. In *Bombus terrestris* the tibia is smooth on the outer surface; the inner is covered with long, stiff hairs, which with the tibia, form a little depression; into this the pollen is brushed by the short hairs of the tarsus. In the honey bee the arrangements are similar, except more perfect

FIG. 12.

for collecting pollen from the anthers. There are eight or nine rows of hairs. The pollen from the anthers is transferred to the surface of the tibia or hairs, to which it readily adheres. Behrens says: "After the process of collecting has been carried on for some time, the pollen forms in thick yellow masses, which completely envelop the legs. Laden with the fruits of its toil, the insect wings its way homeward and deposits them in the bee-hive."

Butterflies and Moths.

It has been said that if [the chief divisions of insects are to be arranged in the order of their importance as pollinators of our native flowers, the first place must be given to bees (*Hymen-*

FIG. 13 A.

Fig. 13 A. A butterfly resting on a cluster of flowers Natural size. (After Behrens.)

FIG. 13.

optera), while the butterflies and moths (*Lepidoptera*) take only the second or third place, before or after the flies (*Diptera*). But if the arrangement is based on the degree of adaptation to flowers, *Lepidoptera* undoubtedly take the first place, as it is the only order which throughout, and not only in certain of its families, is fitted for obtaining honey. In the perfect state, butter-

flies, so far as they take food at all, which is not the case in all species, restrict themselves almost entirely to honey, and since they take no further thought for their young than to lay their eggs sufficiently concealed upon the food plant, their mouth parts have been quite free to adapt themselves to the easy obtaining of honey from various flowers. This adaptation is attained by the great development of the maxillary laminae with a suppression of the greater part of the remainder of the mouth organs. The labrum and mandibles

are aborted. The laminæ of the maxillæ are transformed into two immensely long, hollow, rounded filaments provided with semi-circular grooves on their inner surfaces, thus forming a tube when placed in close apposition. In a state of rest this tube is spirally coiled and concealed between the labial palpi. This account of the insects is mainly taken from Mueller's work. The chief pollinators of the *Lepidoptera* are the butterflies, moths and hawk-moths. The butter-

FIG 14.

flies are diurnal visitors, and when on the wing flutter to and fro; when on the flower their wings are folded back. (Fig. 13 A). The moths and hawk-moths are nocturnal visitors. Moths do not take a position like butterflies when collecting honey, but hover over the flowers with their wings in rapid motion. Some of the *Sphingidae* or hawk-moths have very long tongues. A species found in Brazil has a tongue between ten and eleven inches long. In the United States

and Mexico some of the hawk-moths have tongues several inches long.

Flies and Beetles. So far as diet and visitation are concerned the flies are very important in the pollination of flowers. The most important are drone and syrphus flies. Many of these species depend on nectar

FIG 15.

Fig. 15. Flies. Beginning from the left, bumble-bee fly (*Bombylius major*), natural size. *Empis livida*, 4 times enlarged. Syrphus fly (*Syrphus*). (From Behrens' text book).

and pollen. Their adaptations are such as to allow them to collect honey and pollen. *Rhingia* and *Eristalis* have a complicated mouth structure. The bee-flies (*Bombylius*) are also provided with a complicated sucking apparatus. (Fig. 15). In flying they carry their probosces forward and ready for action. They have the power of detecting concealed nectar in flowers in a most marked degree. Thrips enter all sorts of flowers, which they are enabled to do on account of their small size. They feed on both pollen and honey. (Figs. 12 and 13).

Beetles in some cases show adaptations to utilize nectar and pollen, but there is a very marked difference in species and sub-orders. "None of our native plants," says Herman Mueller, "are fertilized exclusively or mainly by *Coleoptera*." The large genus *Meligethes*, which are small insects and can creep into most flowers, is of much importance in pollinating flowers. In flowers where the honey is exposed (*Cornus*,

etc.) many species of beetles lick the honey. In flowers like Plantain (*Plantago*) where the honey is concealed, beetles feed upon pollen. (See figure 16). Tropical and sub-tropical beetles have in some cases excellent adaptations to obtain

FIG. 16

Fig. 16. Beetles—I to the left, *Cerocoma schaefferi*, natural size. II head ten times enlarged. (I and IIa) Longicorn beetles. I *Pachyta octomaculata* 3 times enlarged. II ab *Leptura livida*. (After Mueller and Behrens' from Behrens' text book of botany).

nectar. Fritz Mueller observed a species of *Nemognatha* sucking the flowers of *Convolvulus* in Brazil. The maxillæ when opposed form a tube like the proboscis of a butterfly, which is, however, not capable of being rolled up.

Reasons for Attraction.

Why do insects go to flowers and of what advantage is it to the plant? Insects go to the flower because it offers food, nectar, pollen, or other substance. The insect must care and provide for its young. Plants would not long provide this food without some advantage accruing to them, hence we have reciprocal adaptations. Note as an illustration the adaptation in sage, clover, etc., or in certain nocturnal Lepidoptera that lay their eggs in the flowers of some pinks, as Soapwort. The larvæ after hatching, feed on the young ovules and seeds. When mature they bite a hole through the side wall of the ovary and escape. These insects do not

require all of the ovules. Shelter is another reason why insects go to flowers, as in Indian Turnip, Skunk Cabbage, e.

Modes of Attraction. The structures that attract insects are, (1) large size, form, color, and odor of flowers, (2) food (pollen, nectar), material for the construction of nests, shelter as in Arum and Indian Turnip, places where the eggs hatch and later the larvæ feed on the ovules, as in Yucca, etc.

Certain insects are excluded because of the color and odor of flowers.

Herman Mueller classified flowers, with reference to their insect visitors, as follows:

Pollen Flowers. Furnish insects with pollen only, Poppy, etc.

Flowers with Exposed Nectaries. Adapted to various kinds of insects, nectary shallow, not highly colored, yellow, white, etc.,—Galium, Elder.

Flowers with Half Hidden Nectaries. Honey visible during warm sunshine, number of visitors reduced, long tongued insects have increased,—Cruciferæ, Ranunculus, Fragaria.

Flowers with Concealed Nectaries. Special adaptation to a particular class of insects not developed. Short tongued insects debarred, as in Mentha, Oxalis, Geranium.

Flowers in Heads, Nectar Concealed. Flowers rendered attractive because of the massing,—Composites, Scabiosa.

Bee Flowers. Adopted to Hymenoptera. Short tongued insects excluded,—Gentian, Digitalis, Columbine.

Lepidoptera Flowers. Nectar deep seated, in tubes, spurs can be reached only by the long tongues of these insects. Flowers fragrant. Diurnal flowers as Silene and

Lychnis; nocturnal as in *Saponaria officinalis* and *Nicotiana affinis*, etc.

Carrion Flowers. Dull in color, yellow, brown, disagreeable urinary or carrion-like odor. *Stapelia*, *Crataegus*, *Smilax herbacea*.

Deceptive Flowers. Insects (flies) attracted by false nectaries. (*Parnassia*).

Attraction of Insects. After having briefly considered the structure of insects it is now in order to take up the attractive features of flowers. I think no one can doubt that bright colors assist greatly in attracting insects. Not all insect pollinated flowers are of bright color. Many flowers that are pollinated at night are white, as in —

FIG. 17.

Fig. 17. Nectaries. I. Buttercup (*Ranunculus acris*); II. longitudinal section; III. Yellow Rattle (*Rhinanthus*); IV. Umbellifer (*Anthriscus sylvestris*); V. Monk's hood (*Aconitum napellus*); III. three times enlarged; II. eight times enlarged; IV. six times enlarged; V. natural size. n. nectary; b. petal; t. nectar; f, k, ovary. (After Behrens.)

Datura and *Nicotiana*. Some night pollinated flowers are pink and other colors, as in *Phlox paniculata*.

Grant Allen says: "We can hardly resist the inference that the colored whorls represent an intensification of the natural tint in growing shoots and floral organs, slowly modified by the selective action of the insect eye." "Mueller, who has carefully noted flowers and their insect visitors, observed

31 distinct visitors upon the purple colored flowers of *Malva sylvestris* and only four on the small white flowered *Malva rotundifolia*, *Heracleum spondylium* 118, *Aegapodium podagraria* 104, *Anthriscus sylvestris* 73, *Daucus carota* 61, *Cnicus arvensis* 88, *Centaurea jacea* 48, *Tanacetum vulgare* 28. He says although it is impossible in statistical tables to take into account the various conditions which may modify the visits of insects, the general law holds good that the more conspicuous flowers are visited more frequently than others.

Mr. Robertson well shows that: "Concealment of nectar, however, accomplishes one important result that cannot be accomplished by a change in time of blooming, and that is the simultaneous exclusion of flies and short-tongued hymenoptera. The effect of concealment of nectar can only be ascertained by comparison with a form having free honey, and blooming at the same time with *Eryngium* and *Cicuta*."

The first condition which seems to be a departure from the original type readily to induce departures of a more serious nature is an aggregation of flowers in a more or less close cluster. In this case the lower lip loses its distinctive function both as a vexillary organ and as a landing place. Both offices are immediately assumed by the inflorescence itself. [As long as the flowers remain separate, they attract the insects which are pleased by the special floral form and are adapted to it. But when the flowers become clustered they attract less specialized insects to what appears an undifferentiated color mass. In a similar way, separated flowers are only readily visited by insects to which the lower lip forms a convenient resting place. But when the flowers form a compact inflorescence, a landing place is formed by the flower cluster. Even when the floral structure remains

the same, I always expect to find less specialized insects on the crowded flower."

[The relation between conspicuousness and pollination of flowers is noticeable in some flowers, as in *Lysimachia vulgaris* of which two forms occur, one in which the parts of the flower are larger and colored more intense; in this case self-pollination rarely occurs; but a form which grows in shaded places has smaller and less conspicuous flowers and these are seldom visited by insects.] An equally instructive lesson is afforded by the small heart's ease (*Viola tricolor*). The

FIG. 18.

Fig. 18. Nectaries. I. to the left, Hellebore (*Helleborus viridis*). II. Columbine (*Aquilegia vulgaris*). III. Violet (*Viola odorata*). I. and II. three times enlarged. I. to the right, Parnassus (*Parnassia palustris*). s. nectary. n. portion where nectar is secreted; f. stamen. b. petal.

species has two varieties. The large flowered variety with conspicuous flowers, variety *vulgaris*, which has given rise to our pansy, is frequently visited by bumble-bees and other insects. In fact there is no occasion for self-pollination since insects carry pollen from one flower to another. The variety *arvensis* on the other hand is smaller and is a weed in gardens and fields. It is seldom visited by insects. Yet in both cases the spur of the lower petal contains the honey. *Rhinanthus crista galli* variety *major* is abundantly visited by insects while the variety *minor* is not. It follows from this that colors are important in pollination.

Color Variations. Changes in colors of different species must be of advantage. Take a meadow in which here and there occur groups of yellow flowered meadow parsnip (*Zizia*), a little distance away is the scarlet painted cup (*Castilleja coccinea*). In late summer the white flowers of spotted cow-bane (*Cicuta virosa* variety *maculata*) a group of yellow flowered goldenrod (*Solidage Missouriensis*) are contrasted and the wild yellow lily (*Lilium Canadense*) is wholly unlike the purple fringed orchis (*Habenaria psycodes*). The change in colors is often conspicuous in closely related species, especially in some highly modified flowers like *Phlomis*, *Lamium*, *Salvia*, *Delphinium*, *Aquilegia* and *Aconitum*; these species usually bear violet, blue, pink or purple flowers. But when these are visited by the same class of insects and growing in close proximity some of the species have a different color, otherwise the end desired would not be reached. "Our species of show this color range beautifully. *M. didyma* is bright red; *M. fsitu-losa* is rose color varying to white; *M. Bradburiana* is pale

FIG. 19.

Fig. 19. Guides to honey. I. Pansy (*Viola tricolor*). II. Carthusian Pink (*Dianthus carthusianorum*). III. Wound-wort (*Stachys palustris*). IV. Field pink (*Dianthus deltooides*). [After Behrens]

purplish white; *M. Punctata* is yellowish." Some of our violets are blue, some are white, others yellow. The cardinal flower (*Lobelia cardinalis*) is bright cardinal; great lobelia

(*Lobelia syphilitica*), blue. It is true that these flowers do not always occur in the same place, yet in some cases they are adapted to the same general class of visitors and it must be of some advantage to have a contrast in colors. It is noteworthy also that some species under different conditions show changes in the color of flowers. Kerner von Marilaun cites a species of *Campanula* (*C. trachelium*) which has white flowers in the neighborhood of Brenners, Austria, but in the valleys of the limestone Alps the flowers are blue. The alpine flora of the Rocky Mountains is remarkable in showing changes in the colors of flowers from one altitude to another.

The genus *Delphinium* is remarkable in showing color variations. A large larkspur, common everywhere in Iowa, is described as having blue flowers, but the form commonly found at Ames, Iowa, and LaCrosse, Wisconsin, is whitish with occasionally a slight tinge of blue. Another species, *D. tricornis*, which occurs in southern Iowa usually has blue flowers, but on the limestone cliffs at Glencoe, Missouri, only white flowers occur. I was therefore agreeably surprised to find that in the great American bottom opposite St. Louis near Falling Springs, in deep rich woods a beautiful pink form occurred. Our painted cup (*Castilleja coccinea*) usually has red flowers, but at Madison, Wisconsin, where I noticed the plant for several years in a swamp, the yellow flowered form occurred. Mr. Upham, however, states that some years upon districts ten to twenty miles in extent the flowers are all yellow, elsewhere scarlet with occasional yellow flowers intermixed. Fritz Mueller has observed that some plants do not flower continuously, but concentrate their efforts to certain days. A species of *Cyphella* (one of the *Iridaceae*) was observed in Itajahy, Brazil, to flower in profusion along the roads for miles, but the following day it was not observed.

In the bell-flower (*Mertensia Virginica*) the flowers at different stages are variously colored. The buds are reddish, when the flowers open they are violet; when fertilization has taken place they change to blue. This peculiarity of changing color after fertilization occurs in many flowers like Missouri currant (*Ribes aureum*), cotton (*Gossypium herbaceum*), horse-chestnut (*Aesculus Hippocastanum*), buckeye (*Aesculus glabra*), etc. This change in color, it is thought, is developed to indicate to the insect that its services are no longer required. Be this as it may, it is interesting to know that color changes do occur. An insect attracted by colors or odors should lose no time after it reaches the flower to get the nectar. Many flowers are therefore characterized by producing certain marks which point toward the nectar, and as some one has said, "These marks are to the insect what the finger-post is to the wayfarer, guiding and directing him to his desired destination." These marks occur in the form of deeper colored portions of the petals, sepals, etc., lines or hairs on the surface of the corolla, stamens, etc. In the pansy these guides consist of lines that are colored blue or purple. On the rose-colored petals of some flowers there are a number of black rings, lines, etc. We must now consider very briefly, nectar. Nectar has been defined by Prof. Trelease as a "fluid always, usually sweet, often odorous, which is elaborated in any part of a plant, remaining where formed or making its way to some other part; its *raison d'être* being the necessity for the removal of some useless or injurious substance, or for some provision to attract nectar-loving animals to the plant for some definite purpose." It is well known that special parts of the flower or plant elaborate nectar; these are commonly called nectar glands. The minute anatomy of these has been

studied by Trelease, Behrens and others. Trelease has divided nectar glands into floral and extra-floral. Floral: Receptacle, pistil, stamens, corolla, and calyx. Extra-floral: Calyx, ordinary bracts, specialized bracts, involucre, ped. uncle, and leaf. The order *Ranunculaceae* is interesting as regards the secretion of nectar. Some flowers are anemophilous and without nectar, as meadow rue (*Thalictrum dioicum*), etc. (In buttercup (*Ranunculus flammula*) the honey is secreted by little scales at the base of the petals.) In *Ranunculus auricomus* the honey glands are at the base of the petals. (In the pasque flower (*Anemone patens* var *Nuttalliana*) honey is secreted by rudimentary stamens.) In a species of clematis (*Atragene alpina*) honey is secreted by the basal half of the filament. In marsh marigold (*Caltha palustris*) honey is secreted by the pistils. In the columbine (*Aquilegia Canadensis*) the honey is secreted by a fleshy thickening in the extreme point of the spur of the petal.) In larkspur (*Delphinium azureum*) the honey is secreted by the two upper petals which are inclosed by the spurred upper sepal. In *Aconitum napellus* the two posterior petals are developed into nectaries. (In *Salvia* and other labiates the nectar is secreted by a disc-shaped gland under the pistil.) In borage (*Borrago officinalis*) it is secreted by the fleshy base of the pistil.) This is retained by a short tube formed by the bases of the stamens. In toad flax (*Linaria vularis*) the honey is secreted by a prominent enlargement at the base of the ovary. After the honey is secreted it passes down a smooth, narrow groove which is lined by short, stiff hairs, and thence to the tip of the spur.

Odors of Flowers.

(Odors in flowers are due largely to the presence of nectar, but some flowers have odors without nectar.) A bunch of hepaticas often pro-

duces a decided odor, but there is no visible nectar.)

The odors of flowers have been divided into five groups: Indoloid, aminoid, paraffinoid, benzonoid, terpenoid. The indoloid odors are frequent in aroids, stapelias, aristolochias and some orchids. These carrion like odors are attractive to insects the feed on carrion, like some flies and beetles. The flowers have vivid spots and reddish brown veins. The aminoid group is closely related to the above, and is derived from the amido derivatives in which one, two or three parts of the water in the ammonia is replaced by the radical alcohol.

In hawthorn (*Crataegus*), the odor is due to trimethylamine. It is similar in the flowers of pear (*Pyrus communis*.) Somewhat different is the odor in manna ash (*Fraxinus ornus*), horse chestnut (*Aesculus Hippocastanum*), tree of heaven (*Ailanthus*).

The benzoloid odors occur in various species of *Dianthus*, the odor of *Asperula odorata*, lily of the valley (*Convallaria majalis*), *Heliotropium*, *Reseda odorata*, etc. From this class one might distinguish special odors as in heliotrope, violet, vanilla, etc. (It is also noteworthy that these same odors occur in plants distantly related.) Carnation odors occur in some orchids as *Platanthera*, also in *Orobanche*, Missouri current (*Ribes aureum*), narcissus (*N. poeticus*) The paraffine odors occur in *Valeriana officinalis* *Ruta graveolens*, grape (*Vitis vinifera*) honey locust (*Gleditschia triacanthos*.) The odor from newly filled honey combs is allied to some of the odors that belong to this group, as buckwheat, white and other clovers.

The last group comprises the aetherial oils but more properly terpene, these occur at times in certain glandular hairs or other parts of the plant, seldom in parts of the flower,

but the odor of citcus flowers belongs here, also in certain species of magnolia (*M. Yulan*,) artillery plant (*Dictamnus fraxinella*).

(It is to be noted also that some flowers produce several kinds of odors, and it is especially important from our point of view to recognize that some plants, although closely related, have entirely different odors.) *Daphne alpina*, vanillin; *D. Philippi*, violet; *D. Balgayana*, carnation. Kerner von Marilaun says anyone who is familiar with the genus *Rosa* will recognize such species as *alpina*, *pimpinellifolia*, *arvensis*, *Indica*, *moschata*, *canina*, *gallica* and *cinnamomea* by their odors with closed eyes.

CHAPTER V.

SPECIAL ADAPTATIONS.

Ranunculaceae. Members of this family shows various adaptations to pollination. Some of the flowers are very conspicuous and are adapted to long-tongued insects, as species of columbine, (*Aquilegia*), *Delphinium* and *Aconitum*. Buttercups, with shallow and unprotected nectar, are adapted to a wide range of visitors, Hymenoptera, Diptera, etc.

Clematis Virginiana, L. The flowers are borne in large conspicuous clusters, dioecious. The nectar is easily accessible and hence numerous small insects are attracted. Robertson stated that three-fifths of the visitors are flies. Some of the species of *Clematis*, like *C. Jackmanii*, have very conspicuous flowers. The European *C. recta* L. is proterandrous and without nectar. In *C. integrifolia*, the inner stamens secrete nectar. The *Clematis Pitcherii*, Torr. & Gray, which flowers much earlier, is adapted to bumble bees. In this species the filaments which secrete the nectar are closely approximated so that bees are admitted by a small opening. Robertson has made an interesting comparison of the insects visiting *Isopyrum biternatum* Torr. & Gray, and *Clematis Virginiana*, L. The former, which blooms in early spring, is visited by 31 Hymenoptera, the latter by 9; bees and Syrphidae are less abundant on the latter. It is visited also by 10 Tachinidae, 7 Muscidae and 11 other Diptera; the former by 4 of these.

Delphinium The flowers of the genus are conspicuous. The European *D. elatum* L. as well as *D. consolida* L. are frequently cultivated; *D. azureum* michx. flowers in July. The *D. tricornes*, michx. is native to Southern Iowa. In the *D. elatum*, L. the five blue sepals are conspicuous, very irregular, the upper one prolonged into a spur. Petals four, irregular, two arch over the entrance to the spur, the hairs form a path-finder to the nectar which is secreted by the petals and contained in the spur. The pistil matures first and bends down before dehiscence, but when mature it points upward. I have seen *B. pennsylvanicus* in Wisconsin. It is also visited by *Synhalonia*, and such *Lepidoptera* as *Danaïs* and *Papilio*.

Aquilegia Canadensis, L. The American Columbine is frequent in deep rich woods and flowers in early May. The conspicuous, scarlet flowers are yellow inside and pendulous. The five sepals are regular and colored like the petals. Petals five, hollowed out into long, nearly straight spurs, the opening is wide enough to admit the head of a bumble bee. The nectar, which is secreted by the fleshy part at the end of the spur, occurs in the upper part of the same. The flower is adapted to long tongued bumble bees; these reach the honey by hanging on to the flowers, grasping the base of the spur with fore legs, and with their hind legs to the column forward by the stamens and pistils.

Berberidaceae. Several members of this order are cultivated for ornamental purposes. In the common Barberry (*Barberis vulgaris* L.)

The yellow flowers are borne in racemes and contain some nectar, which is secreted by two fleshy, orange colored glands at the base of each petal. The honey collects be-

tween the stamens and ovary. When the insect visits a flower it thrusts its head into one of the angles and in doing so comes in contact with the stamens which are sensitive, they come forward and shed their pollen on the insect. It now leaves the flower and as Hermann Mueller says, "Thrusts its head or proboscis into the flower in as many different ways as the different positions of the flower require; now under the stigma, now over it, now to the right, now to the left. Its head

FIG. 20.

Fig. 20. Flower of common barberry (*Berberis vulgaris*). 1. flower seen above; a, and sepals; b', inner petals; c, nectaries; d, filaments; e, stigma; 2, position of the stamen after springing upward; 3, petal with the two thick, fleshy orange nectaries; 4-7, stamen in different stages of dehiscence. (After Hermann Mueller.)

must soon be dusted all round with pollen and it must fertilize every succeeding flower that it visits."

Fumariaceae.

Members of this order are among the prettiest of our early flowers. *Dicentra spectabilis* D C, Bleeding Heart, is commonly cultivated. The purple colored flowers are heart-shaped pendulous, and contain the honey in the two pouches at the base of the

petals. Two of the petals are narrow, united at the top, and enclose the six stamens, three on each side. When a bee (*Bombus*) hanging from the flower puts its proboscis into one of the two channels which occur on the petals, it presses the hood and stamens to one side, but the style, which is stiff, remains in position and is rubbed by the bee's body. A bee goes both to the right and left sides on each visit. In this way it is certain to carry away some of the pollen.

Corydalis cava. The flowers are borne in racemes. Each flower has two small, scale-like sepals that soon fall off. The four petals occur in two pairs; one being spurred. The nectar is secreted in the lower end. The other petal serves as a support for insects when in the act of obtaining nectar. The inner petals enclose the stamens and stigma. This has been called the hood. It is indented on both sides and when touched the six diadelphous stamens and pistil are liberated. Behrens says: "Previous to the opening of the flower the pollen from the anthers is shed upon the stigma while it lies in contact with them." Self-pollination would seem easy, but if the flowers are enclosed by a gauze bag no seeds will set. The insect on reaching the flower pushes its head between the hood and upper petal, the hood is pressed downwards and the pollen rubs against the lower surface of the insect's body. The hood returns to its normal position and encloses the stamens and pistil.

Cruciferae. The Cruciferae show great uniformity so far as the structure of the flower is concerned but variability in the number and position of the nectar glands. The honey secreted by the glands remains on the gland or is found in spaces between them. They are visited

by flies, especially Syrphidae, and small Hymenoptera. The honey bee is abundant on some species of *Brassica*. Some species are also visited by Lepidoptera.

Brassica nigra Koch. Common mustard is a wayside and garden weed. The yellow flowers are conspicuous, arranged in masses, and have a pleasant odor. It has four nectar glands, two outside at the base of the petals and two in front of the short stamens. The nectar occurs in large drops on the glands where it is taken by the insect which in doing so comes in contact with the pollen on both long and short stamens, leaving some of the pollen on the capitate stigma. In the absence of cross-pollination, self-pollination occurs.

Violaceae. Our violets are all early flowering and the only species to be had during the summer is the Pansy (*Viola tricolor* L). In the cultivated forms the colors have been greatly changed. Three of the petals have conspicuous pathfinders. The corolla is irregular, the lower petal spurred at the base; stamens closely surround the ovary, the two lower spurred. The spur acts as a nectar gland while the lobed, hollow spur of the petal acts as a receptacle. The insect thrusts its proboscis close under the stigma into a hair-lined groove on the lower petal. The anthers shed their pollen into this groove and thus the proboscis becomes dusted with pollen. A small projection below the stigma prevents the pollen on the insect from coming in contact with the stigma. As the insect goes to another flower it leaves some of the pollen on the stigma.

Of *Viola pubescens*. Ait. Robertson says: "This is yellow with dark nectar-lines. The petaline spur is little more than a gibbosity. The nectar-searching processes of the

lower stamens are very short, being much wider than long. The summit of the peduncle and the flower axis are strongly curved so as to throw the spur well backwards, giving the flower a characteristic appearance, and this serves to limit the insects visits much more than the mere length of the spur."

In regard to visitors Robertson says: "Really, the proper visitors are bees which are small enough to use the beard as a support; so that the bumble-bees and butterflies may properly be classed as intruders, even when they reverse. For the proper visitors of the bearded violet we must look to small bees, among which the *Osmias* are most important."

Many of the violets produce cleistogamous flowers.

Caryophyllaceae.

The order shows considerable variations as regards insect visitors. The common door yard weed *Stellaria media* Smith is adapted to short-tongued insects while *Dianthus*, *Saponaria officinalis*, *Lychnis* and others are visited by more highly specialized forms. In the more highly specialized form of flowers, odors and colors are conspicuous.

Saponaria officinalis, L. The Bouncing Betty, is a common weed in places and is adapted to nocturnal *Lepidoptera*. Species of *Sphinx* are common here at Ames we have observed. *Hemoris thisbe*, *Sphinx Carolina*, *S. Chersis*, *Philampelus*, *Deilephila lineata*. The nectar is secreted by a little ridge on the receptacle. Nectar is contained at the base of the tube. The flowers are white and have a strong odor in the evening. The calyx tube is 18 21 mm. long. The flower is strongly proterandrous. The outer stamens protrude first, dehisce and spread apart. Then the five inner stamens dehisce, the styles are still

closed, when, however, the anthers have withered the two styles lengthen and spread apart.

Geraniaceae. The Common Cranesbill, (*Geranium maculatum*, L.) is common in woods. The dark

lines of the petals converge to the base of the petals where the nectar is found, which is secreted by five glands at the bases of the outer stamens and protected from rain by hairs.

The flowers are proterandrous; the five stamens discharge their pollen over the center of the flower and afterwards the five inner do the same. The anthers commonly drop off before the stigmas expand. Robertson observes that during rainy weather they may be in the male stage for several days, but during warm weather they go through both stages the same day. It is visited by the honey bee, bumble bees, *Diptera* and some *Lepidoptera*. Some of the European species have lost all power of self-fertilization.

Oxalis. Some species of the genus *Oxalis* are trimorphic. Hildebrand found fifty-one species trimorphic.

Geranium. Our commonly cultivated *Geranium* (*Pelargonium zonale*, Willd) colors, various, in many darker zones leading to base of upper petals, these overlap, forming a groove leading down to the nectary, which is made up of the base of one sepal, forming a long narrow tube. Nectar is secreted by the hairs on lower side near the base of this tube. The flowers are proterandrous. The seven stamens mature first, five before the two shorter which occur in front of the opening to the nectar tube. After dehiscence the pistil lengthens and the style spreads out. The geraniums with us are frequently pollinated by humming birds.

Vitaceae. Flowers very commonly polygamous or dioecious, flowers greenish, inconspicuous, but very fragrant ovary with an adnate fleshy disk of five nectar glands which secrete the nectar. This bears the petals and stamens, calyx short. The stamens held by the petals which separate only at base, which forms a kind of a head, when mature the stamens are released, thus allowing the pollen to be thrown on the insect.

FIG. 20.

FIG. 20. A, Flower before the removal of petals *a*. B, After removal of petals, *b*, *c* stamens which have dehisced, *d* just in the act of dehiscence.

Leguminosae. Many of the legumes are excellently adapted for insects. In the Papilionaceae the flowers are irregular and with some exceptions expose the stigma and pollen to contact with the ventral surface of the insect. The two lower petals are united to form the keel and enclose the reproductive bodies. The wings serve as a resting place for insects, to depress the keel, keep it in place and bring it back to its place after depression. The manner in which the keel returns to its place varies in different species. Most of the *Leguminosae* are insect pollinated, though some,

like *Erythrina*, are adapted to humming birds.

Phaseolus vulgaris L. The common bean is abundantly self-pollinated, it has interesting adaptations for securing cross-pollination. The flower of the bean consists of the green calyx and the corolla, which is made up of five parts, the upper part called the standard, two lateral wings, and a keel made up of two petals. The keel is spirally coiled and contains the stamens and pistil. The oblique stigma is on

FIG. 21.

Fig. 21 Common bean (*Phaseolus vulgaris*). 444, the flower. 446, showing spirally coiled keel. 448, part of keel removed, showing style 447, the figure to the right showing style and pollen only. (After Gray)

the tip on the style, which is bearded, near the end on which the pollen is discharged. An insect in searching for the nectar at the base of the flower lights on the two lateral petals, coming first in contact with the stigma, deposits pollen from another flower. The weight of the insect causes the style to protrude. In scarlet runner (*Phaseolus multiflorus*) the arrangement is similar except that the keel with its style is so bent that when pressed down, the style

comes out, points downwards and towards the left, and Francis Darwin has shown that the tenth stamen, which is free, bears an appendage which prevents a bee from taking the honey, except from the left side. On the college grounds the early flowers are invariably sterile. But those produced in August are fertile.

In the closely related *Strophostyles angulosa* Ell. the keel is bent strongly to the right and occurs in such a way that its tip stands over its base. Robertson says: "The base is large and sac-like and is produced above into a ridge which opposes the passage to the nectary. The left wing is turned to the right so that the bee is required to alight upon the right side, and she enters the flower between the tip and the basal process of the keel. Seizing this process with her front feet, the bee pulls the keel downward and backward, whereupon the stigma and the pollen-laden brush of the style sweep out over her thorax. In this way the stigma receives pollen already deposited by another flower, and the style-brush leaves a new load."

This plant, along with several other *Leguminosae*, especially the Cowpea of the South, *Vigna Sinensis*, Hassk. has conspicuous extra floral nectaries, on which *Vespa maculata* and *Formica* are common. Robertson reports having found several *Hymenoptera* (Andrinidae, Vespidae, Formididae,) *Diptera* and *Hemiptera*, on *Strophostyles angulosa*, Ell.

Apios tuberosa. Another near relative of *Phaseolus* is *Apios tuberosa*, Moench. which has a large standard with a rather firm texture, at the tip of the standard is a small boss, as seen from the back, or a shallow sack as seen from the front. The sickle shaped keel is arched and fixed into the notch at the upper end of the standard and it remains in this position unless touched by an insect. When an insect touch-

anther, to this is attached a thread-like affair known as the filament. But in the case of clover, however, the filaments are united to form a tube; the anthers contain the pollen. The pistil is also found in the keel. The lower portion is the ovary, the narrow neck is known as the style, the tip is the stigma. The color of the clover flower is especially attractive to insects. The honey which the insect seeks is contained in the tube formed by the union of the fine thread-like bodies, or filaments.

When an insect like the bumble bee lights on the flower, it uses the keel and wings (the latter being attached to the tube containing the nectar) as a resting place, its weight pressing the keel down and causing the pistil and stamens, the latter being somewhat shorter than the pistil, to come in contact with the under side of the bee's head. The insect is certain to leave some of the pollen from another flower on the stigma. The honey is obtained by the insect when it thrusts its proboscis into the united filaments of the stamens, the tube thus formed has a slit on the upper side to give place for a free tenth stamen. Self-pollination, or pollination of the flower from its own stamens, is not excluded, as the insect leaves the flowers.

In order to reach the honey an insect must have a tongue from .3543 to .3937 inches (9 to 10 millimeters) long. The honey lies from .2755 to .3937 inches (7 to 9 millimeters) deep. Any insect sufficiently heavy to press down the keel can pollinate the flower. Bumble bees are, of course, the common pollinators. Prof. Osborn informs me that he has observed two common species (*Bombus pennsylvanicus* and *B. fervidus*). We have found *Bombus americanus* *B. fervidus*, *Apis mellifica*. We also observed *Alydus pluto*, *Enchistus variolarans* of *Hemiptera*. Of the *Coleoptera* the

following were observed: *Lachnosterna gibbosa*, *Tetratopus femoratus*. My friend, Mr. Robertson, records several more. [The honey bee can, no doubt, pollinate red clover, as they often collect pollen.] I have taken an interest in bees for many years and have given some attention to red clover and honey bees. The following paragraph, from a paper published in 1888, may be of interest: "In the summer of 1883, in the vicinity of La Crosse, Wisconsin, I noticed large numbers of honey bees on the flowers of red clover. In many cases they were actively collecting pollen, but in some cases honey through perforations in the corolla, made by some other insects." Hermann Mueller says the honey bee "usually visits the red clover only for its honey, which its proboscis is not able to reach in a legitimate manner—yet now and then I have seen hundreds of honey bees on a patch of red clover, all busy collecting pollen." Here at Ames I have seen red clover visited by several butterflies, especially the large, red butterfly (*Lanaïs archippus*), cabbage butterfly (*Pieris rapae*), yellow butterfly (*Coleus philodice*), also *C. eurytheme* and a fly (*Bombylius*). Red clover is especially adapted to larger bees,] but Hermann Mueller of Germany, and Robertson, of Carlinville, Illinois, records a large number of butterfly visitors. Thirteen out of twenty visitors belonging to the butterfly family were observed in Illinois. [There is no question but that they do occasionally pollinate red clover and effect cross fertilization.] Robertson writes. "Bumble bees depress the keel so that their heads and proboscides are well dusted with pollen, but butterflies can insert their thin tongues without depressing the keel, and even if they get a little pollen on their thin proboscides, it is apt to be wiped off by the closely approximated tips of the petals, which close the mouth of the flower.")

Th. Pergande expresses the belief that different species of thrips, which were found in many kinds of flowers, may effect cross-pollination. Osborn informs me that two kinds of thrips are common in clover blossoms. *Thrips tritici* and *Phloethrips nigra*, but these certainly cannot generally effect cross-pollination.

Can the honey bee effect cross-fertilization in Mammoth clover (*Trifolium medium*)? It probably can do so as it does in common red clover. I have not studied the flowers of mammoth clover carefully, but so far as I can see, the flowers of the forms in the college collection are about the same size as those of red clover. One form has much smaller heads and the flowers are somewhat smaller, but I am inclined to think that mammoth clover is pollinated principally by bumble bees. The work of honey bees in pollinating white and alsike clover is well known, in fact, they can easily accomplish this. One other thought suggests itself to me in this connection. I believe that it is generally supposed that the second crop of clover produces more seed than the first. This, I think, is due to insects, there being a much larger crop of bumble bees at the time of the second bloom than during the first bloom.

White Clover. The flowers of *Trifolium repens*, L., are massed together in the form of a head and hence are quite conspicuous. The odor also helps to attract. The standard has a groove which leads to the nectary. The nectar is secreted at the bottom of the tube formed by the union of the filaments and can only be reached by the openings, one on each side of the free tenth stamen. An insect, in order to reach the nectar, puts its proboscis underneath the standard. It uses the wings and keel as a resting place, pressing down the latter and causing the stamens and pistil

to protrude. The stamens and pistil come in contact with the lower surface of the body. When the insect leaves the flower the parts return to their positions. At the base of the expanded part of the wings is a pouched swelling which causes the wings to cohere with the keel and serves the purpose of bringing these back to their positions. Honey bees are the active pollinators. It is also pollinated by small *Lepidoptera*. Short tongued insects are included. Self-fertilization seldom if ever takes place. Darwin found that when insects are excluded it is but slightly productive.

Sweet Peas. The flowers of sweet peas are conspicuous as to odor and color. The margins of the wings of the corolla adhere to the keel by a process which folds inwardly, the standard also fits into these wings. It thus requires considerable force to press down the keel which contains the pistil and stamens. The style is flattened and hairy along the inner side. These hairs contain the pollen and as the keel is pressed down the pollen is swept out.

Amorpha fruticosa, L. The flowers are purplish and arranged in a conspicuous spike. In this plant the keel and wings are wanting and the standard surrounds the stamens and pistil which are exerted. The flowers are proterogynous, here at Ames as elsewhere, as observed by Trelease, Robertson, Mueller and Beal. It is visited by *Bombus* and the honey bee here at Ames.

The Lead Plant, *A. canescens*, Nutt., flowers nearly a month later at Ames and is not a competitor with it as it grows in different situations.

Partridge Pea. This leguminous plant is conspicuous in dry situations and has some interesting features, first described by J. E. Todd. These are described by Robertson as follows: "The sickle-shaped pistil is turned

either to the right or to the left, holding the stamens in such a position that it touches the bee upon the side; the flower is therefore an example of what Delpino calls a *pleurotribe* flower. Ten long black anthers with terminal pores turn in an opposite direction from the pistil. The petals are bright yellow, the upper ones are provided with a little red at base which serves as a pathfinder, but not as a nectar guide, since nectar is wanting. All are widely expanded and flexible except the lateral one toward which the anthers turn, which is erect and strongly incurved and so stiff that it commonly breaks on being bent back."

"The flowers are visited exclusively by humble bees, females and workers in search of pollen. Landing upon the anthers they seize them between their mandibles and stroke them downwards with a sort of a milking motion. The pollen being thus forced out of the terminal anther-pores, falls either directly upon the bee or upon the lateral petal which is pressed close against the bee's side. In this way the side of the bee which is next to the incurved petal receives the most pollen. Both right and left-hand flowers are found upon the same plant. A bee visiting a left-hand flower receives pollen upon the right side and then flying to a right-hand flower, strikes the same side against the stigma."

Rosaceae. The plants of this order are adapted to short-tongued insects; then too, the large number of stamens causes it to be sought by a numerous class of *Diptera* and *Hymenoptera*. The nectar is secreted by the wall of the tube of the receptacle. The amount of this secretion varies, in some cases no nectar is secreted. Some of the species are delightfully fragrant, others are without any odor.

Native Plum. A conspicuous plant in woods, sometimes

forming thickets. The white flowers are conspicuous with a decided odor. It flowers from the latter part of April to early May, depending on the season. The flowers are slightly proterogynous, when open they are ready to receive the pollen. Some varieties of the European *P. domestica* L. are more strongly proterogynous. The stamens mature somewhat later. They are as long or a little longer than the style. Self pollination may occur, though in some cases this is prevented by self impotency, in some varieties. *Prunus hortulana*, Bailey, as I have had occasion to observe for seven years, has imperfect flowers. Many flowers of our native plum have since been examined and I have never failed, in some individuals at least, to find this character well pronounced.

In all cases examined the suppression was all in the direction of the pistil. The stamens in all cases were well developed. In these imperfect flowers the pistil is short, scarcely as long as the calyx tube. In the Rollingsstone the pistil is entirely absent in many cases.

To see how generally the pistils were rudimentary, a number of counts were made on branches selected at random on several trees. On the first tree 79 per cent of the flowers counted were perfect and 21 per cent imperfect; on the second tree the flowers 76 per cent perfect and 24 per cent imperfect, while in the third tree but 31 per cent of the flowers were perfect and 69 per cent were imperfect. Prof. Goff has observed similar facts; he states: "Imperfect pistils or an absence of pistils, has also been offered as a reason for infertility in native plums. Unquestionably this defect sometimes occurs. Professor Bailey mentions a wild plum tree of his acquaintance that bears flowers without pistils, also that, in the season of 1892, only about one flower in

twelve of the Newman plum at Cornell University had a perfect pistil. I have made careful observations on this point in our own Plum-trees during the present season and find a marked difference in varieties, as to the percentage of perfect pistils."

The insects most common on the plum are honey bees and other small *Hymenoptera* and *Diptera*. During the evening it is abundantly visited by cut worm moths.

Choke Cherry. The white flowers, borne in long racemes, are conspicuous. *Prunus Virginiana*, L., is likewise proterogynous. Self-pollination as well as cross-pollination occurs. *Prunus serotina* Ehr., which flower several weeks later, has the same general arrangements and like the flowers of choke cherry, have a somewhat disagreeable odor, which accounts for the large number of *Diptera* which visit it.

Washington Thorn. The white flowers are borne in corymbs and are very conspicuous. They are proterogynous. The nectar is secreted in the receptacular tube and is not concealed. It is visited by many *Diptera* and small *Hymenoptera*, among them the honey bee, also some *Coleoptera* and *Lepidoptera*. Of the four species, *Crataegus punctata* Jacq. *C. coccinea*, L., *C. mollis* and *C. tomentosa*, no two flower at the same time about Ames.

Wild Crab. This blooms in and about Ames about the middle of May. *Pyrus coronaria*, L. is one of the most interesting of our native plants. The large, showy and attractive purple-colored corollas are attractive to insects because of the delightful fragrance. The filaments of the numerous stamens form a circle about the summit of the receptacle tube. These are also directed upwards and

inwards, thus concealing the nectar effectually, and barring out short tongued insects. Robertson says: "The nectar is reached by a bee thrusting its proboscis between the separating ends of the filaments," The flowers are proterogynous; self-pollination is prevented because the stigmas are much longer than the stamens.

Strawberry. The flowers of the strawberry are conspicuous because collected in patches. Nectar is secreted

FIG. 23.
Fig. 23. Flower of Strawberry.

FIG. 24.
Fig. 24. Flower of Strawberry.

by the receptacle at the base of the filaments, next to the outer row of pistils where it is held. The flowers are gynodioecious, the female flowers are smaller and bear shorter stamens. The staminate in some cultivated varieties, as the Bubach are very large. The plant may be self-pollinated, although nearly always cross-pollinated. It is vis-

ited by honey bees frequently at Ames and also by species of *Halictus*.

Rubus. The red raspberry, *Rubus strigosus*, Michx., has white petals and is not nearly so attractive as the blackberry (*R. villosus*, Ait.) Nectar is abundantly secreted by the flattened disk between the pistil and filaments which is obtained by bees inserting their proboscides between the stamens and pistil. The stamens are inflected inwardly toward the pistil. The stigma is receptive before the stamens mature. In the absence of insect pollination, self-pollination can take place. Visited by *Hymenoptera*, honey bees frequent. *Rubus villosus* is much more attractive. The petals are large and white. Nectar is secreted as in Red Raspberry but is more difficult for insects to obtain. It is visited by honey bees and Robertson records several species of *Bombus* for Carlinville, Illinois.

SAXIFRAGACEAE. Members of the order are adapted to a wide class of insect visitors. Many of the species occur in colder portions of the world. The Saxifragas are common in alpine and subalpine regions, some occurring in the bogs and meadows of the Eastern and Northern States. Species of the genus *Ribes*, though originally of the colder regions, have a wider distribution. The species of the order vary as to their insect visitors. Most common are the *Diptera* and *Hymenoptera*. Herman Mueller has called attention to the fact that the flowers of many species of the genus *Saxifraga* are proterandrous; the anthers ripen one after another. He also notes that in *Chrysosplenium alternifolium*, L., small snails creeping about over the stigmas and anthers, carry the pollen grains upon the stigma with their slimy bodies. *Parnassia palustris*, L., which is native to Northeastern Iowa, has some peculiar nectar glands. "Each consists of a short, broad peduncle, broadening above into a fleshy disk which

secretes honey in two shallow depressions on its inner side, leaving it fully exposed. Above it gives off seven to eighteen yellow, knobbed, glandular bodies, probably for the purpose of making the nectaries more conspicuous. These yellow, knobbed affairs look very much like little drops of fluid. Mueller states that these drops are quite deceptive, so much so that flies are deceived by their appearance.

Phiadelphus. The flowers are crowded in large, cream-white clusters and are proterogynous. The numerous anthers stand in and around the stigmas before and after dehiscence and are as long as or longer than the pistils. The nectar is secreted in the fleshy disk in the upper part of the ovary. In the absence of cross-pollination, self-pollination can easily take place. It is adapted to a large class of visitors. An east European species with small flowers is proterandrous. The flowers are sweeter scented, being that of pine apple.

Ribes The various species of the genus *Ribes* differ in regard to the depth at which the nectar can be obtained. The *Ribes alpinum* is visited here at Ames by various species, *Diptera* the common honey bee, and *Bombus Pennsylvanicus*. The *Ribas gracile* Michx. and *R. Cynosbati* L. are both early flowering species and are visited by *Apis mellifica*, *Bombus Pennsylvanicus*. The western *Ribes aurcum* Pursh. is frequently cultivated, and has a long calyx tube and small erect petals. The calyx is colored yellow, petals also yellow, flowers very fragrant. The petals, after fertilization change from yellow to bright red. It is adapted to long-tongued bumble bees.

Lythraceae. Loosestrife, *Lythrum Salicaria* L. is a native of Europe but sparingly naturalized

in Eastern North America and frequently cultivated. Flowers purplish, petals six to seven. Spiked Loosestrife is classic because of Darwin's work in connection with heterotristylous flowers. Darwin proved beyond a question that the reproductive bodies, when of different lengths, behave like different species of plants, that is to say, the pollen taken from a short stamen and placed upon the long style in the same flower or plant has no effect. So, too, of all the other stamens taken from the same plant. Darwin also demon-

strated that the pollen grains differ as well as the stigmatic papillae. The pollen grains of the longer stament are green, those from the

FIG. 25.

Fig. 25. *Lythrum salicaria*. 1, long styled flower from above, with two sets of stamens; part of calyx and corolla removed; 2, mid-styled flower; 3, short-styled flower; a, long anthers and stigmas; b, mid-styled; c, short; d, honey gland; f, mid-styled flower viewed obliquely. (After Hermann Mueller).

middle size and the shortest are yellow. The pollen grains also vary in size. The longest stamens have the largest pollen grains and the shortest, the smallest.

In this plant three kinds of flowers are produced. One plant produces only a short style with long stamens and mid-styled stamens; a second plant has a long style with

short and mid-styled stamens; a third has a medium style with short and long stamens. In order to have full and complete fertility pollen must be brought from the long stamens over to the long-styled, short stamens over to the short-styled, and mid-stamens over to the mid-styled form.

The honey in this plant is accessible to a large class of visitors.

Onagraceae.

Evening Primrose is a common weed. It is adapted to nocturnal *Lepidoptera*; but also to long-tongued bees. The flowers are bright yellow, open partially during the day but produces the greatest amount of odor during the evening. Trelease has observed that the *Oenothera sinuata*, L. is visited by the humming bird. Some species of *Oenothera* produce cleistogamous flowers.

Fire Weed. *Epilobium angustifolium*, L. is widely distributed in the northern hemisphere. The flowers are strongly proterandrous. The large and showy flowers are arranged in a spike, the widely spreading petals on short claws. The style is bent downwards. Herman Mueller says of it: "The expanded lower ends of the filaments form a hollow cone which encloses the base of the style and the surrounding honey; where the style issues at the apex of this cone, hairs upon the style prevent the entrance of raindrops, while insects easily gain access between the filaments."

In young flowers the stamens, covered above with pollen, project forward as an alighting place for insects, while the style is still shorter and bent forwards with its stigmas folded together; in older flowers, the empty stamens are forwards, and the style, greatly increased in length, projects forwards with its four stigmas outspread and recurved.

Alighting, sucking, and pollen-collecting are thus all made easy, cross-fertilization in case of insects-visits is insured,

FIG. 26.

Fig. 26. A flower of evening primrose (*Oenothera biennis*) cut lengthwise shows a very long tube. (After Kerner von Marilaun.)

FIG. 26 A.

Fig. 26 A. 3, Pollen of *Oenothera biennis*.

and self-fertilization rendered impossible. In fine weather, sufficient insect-visits are always insured by the conspicuous

color, size, and grouping of the flowers, and the abundance and accessible position of the pollen and honey."

In the Rocky Mountains this species is commonly visited by several species of *Bombus*.

FIG. 27.

Fig. 27. Dichogamous flowers. 1 *Fpilobium angustifolium* showing development of stamens first (proterandrous) with a bumble bee on one of the flowers. See upper flowers. (After Kerner von Marilaun.)

Cucurbitaceae. The Cucurbits are usually said to be monoecious or dioecious, although G. O. Mueller says occasionally polygamous. It has been known for some time that the same species are proterogynous and

dioecious Crozier says in regard to the watermelon: "In making some crosses today on the Volga watermelon, a variety from Southern Russia, I discovered that the so-called pistillate flower possessed stamens."

Cucurbita pepo, Linn. The different forms of this species have the same general arrangement and structure as are found in *C. maxima*. The odor of the large yellow flowers is not so pleasant as in that species, but is rather disagreeable. Nectar is abundant and the insects reach it in about the same way. The flowers open early in the morning and when mature the pollen falls out, frequently filling the bottom of the flower. The grains are very large, round and spiny. When placed in water the spines in several places are thrown off, and in a short time the contents pass into the water.

Insect visitors.—Hymenoptera, *Apis mellifica*, *Bombus pennsylvanica*, *Formica rufa*. Coleoptera, *Diabrotica longicornis* and *D. vittata*, Fab.

Citrullus vulgaris, Schrader. The pale yellow corollas of the watermelon are widely spreading. The honey is secreted at the base of the flower. It is easy to observe how the honey bee obtains its nectar. It uses the petals as a resting place and obtains the nectar through the opening. It first probes one side and then passes over the stamens to the opposite side of the flower from which the nectar is taken. When its work is finished it flies to another flower. Its visits are confined chiefly to one variety but occasionally other varieties are visited. It is noticeable that when flies collect pollen, honey bees flit about the flower a moment, then go to another. The flowers are open all day.

In the insect visitors the Hymenoptera were represented

by *Apis mellifica* and the Diptera by several species of *Syrphus* flies.

Lagenaria vulgaris Ser. The musk-scented flowers of the dipper gourd have a funnel or bell-shaped calyx with a long tube. The white petals are persistent a much longer time than in *Cucurbita pepo* and the nectar is not so easily accessible and exposed as in *Citrullus* and *Cucurbita*. The three stamens effectually block the way for the larger insects. The flower is adapted to humming birds, which can easily get to the nectar with their long tongues. The color and odor would seem to indicate that it is adapted to Sphingidae, but as the plants were so far away observations were not made at night. In addition to the humming bird, *Bombus pennsylvanicus* was observed collecting pollen. *Diabrotica vittata* was also observed covered with pollen.

Umbelliferae. Members of the carrot family are not highly specialized; nectar occurs in open flowers and is accessible to short tongued insects. The individual flower is not conspicuous, and so far as our own species are concerned, are without the attractive flowers, but since the flowers are massed they are rendered attractive. *Zizia* and *Pimpinella* are proterogynous while *Heracleum* and *Sium* are proterandrous. Mr. Robertson speaking of insect visitors says: "The character of the visitors of *Umbelliferae* therefore, must depend upon the insects to which they are exposed, i. e. upon the time of blooming. Indeed, the time of blooming is almost or quite as important as modifications to hide the nectar. If we take three white-flowered forms with exposed nectar, but appearing at different times, we will find the extremes in characters of visitors. Thus, *Eriogonia* shows the highest proportion of bees *Eulophus* the highest proportion of flies, *Cicuta* the highest proportion of

lower *Hymenoptera*. *Zizia*, *Polytaenia* and *Eryngium* agree in showing a preponderance of *Hymenoptera* over flies as an effect of concealment of honey. *Pastinaca*, *Cicuta* and *Sium* show the same result as an effect of time of blooming. Forms with hidden nectar also show marked contrasts on account of time of blooming. Thus, in the case of *Zizia* which blooms in May, one-half of the *Hymenoptera* are bees, while in *Eryngium*, which has more deeply-seated honey but blossom in July, only one-third of the *Hymenoptera* are bees."

Cow Parsnip. This large, coarse perennial grows in deep, rich woods and bears large and broad white umbels. The larger plants have two or three secondary umbels and one of the third order. Robertson gives the proportion of male and hermaphrodite flowers in different umbels as follows: "First order, 0 male and 420 hermaphrodite in nineteen umbellets; Second order, one hundred and twenty male and three hundred and three hermaphrodite flowers in twenty umbellets; Third order, three hundred and eighty-nine male and forty-six hermaphrodite flowers in twenty umbellets." From this table it will be seen that those of the first order are entirely hermaphrodite while those of the third order are almost entirely male. The same relation is borne out here at Ames. The hermaphrodite flowers are proterandrous. It is abundantly visited by *Diptera*, especially *Syrphidae* and by some *Hymenoptera* as the honey bee. In the Rocky Mountains, where I observed the plant, small *Hymenoptera* and *Syrphidae* were common.

Caprifoliaceae. The order shows considerable variation as regards pollination. On the one hand it is well adapted to *Lepidoptera*, *Sphingidae*, birds, and long-tongued *Hymenoptera*, and on the other, in case of *Adoxa*

and *Sambucus*, to short-tongued insects. The *Weigelia rosea*, like *Ribes aureum*, changes its color after pollination.

Honeysuckles. The flowers of *Lonicera sempervirens*, Ait. are nearly regular, trumpet-shaped, the deep red corolla is conspicuous but has little odor. It projects obliquely upwards and the corolla tube is lined with hairs. Stamens five, as long as the style; pistil and stamens maturing at the same time. The nectar is secreted in the lower part of the tube and is very abundant. In this locality the humming bird, *Trochilus colubris*, is a common visitor as are some of the larger *Lepidoptera* as *Papilio turnus*. The humming bird, in a single visit, takes the nectar from a large number of flowers.

In *Lonicera Sullivantii*, Gray. the flowers are irregular, white with a purple tube, and are borne in clusters. The five stamens are situated above the declined style. Nectar is so abundant that it rises in the tube and is protected by a copious development of hairs. It is regularly pollinated by humming bird. *Lonicera Tartarica*, L. the honey is secreted and lodged in the shallow pouch at the base of the tube. It flowers three weeks earlier and has a pleasant odor and is conspicuous because of the color. *Apis mellifica* and *Bombus pennsylvanicus* are frequent visitors.

Compositae. The order is the most extensive of all flowering plants—nearly one tenth of all plants belong to this great family. As an illustration, let us take the sunflower (*Helianthus annuus*) and ox-eye daisy (*Chrysanthemum leucanthemum*). The so called "flower" is an inflorescence known as a head. In the ox-eye daisy, the flower of the outer row of florets, are transformed into a conspicuous white strap-shaped corolla known as the ray-flowers. In the sunflower these are yellow but in both cases they serve

to attract insects. In some flowers as in dandelion, all of the corollas are strap-shaped. In boneset, the ray-flowers are absent.

This large order has some extreme variations, as in *Ambrosia* which is anemophilous. In many the nectar is easily reached by short tongued insects, as in *Solidago* *Achillea*. In some thistles, as *Cnicus lanceolatus*, the nectar can only be reached by long tongued insects. Where the individual flower sometimes lacks in attraction the ray flowers increase in conspicuousness.

Vernonia fasciculata Michx. grows in marshes. The tall stems bear numerous heads of purple flowers. The long tubular flowers are adapted to long tongued bees and flies, also *Lepidoptera*. The flowers are proterandrous, the pollen being carried out by the brush hairs on the style.

The *Eupatorium ageratoides* L. is also without ray flowers but grows in woods. It flowers at the same time that *Vernonia* does. The *E. purpureum* L. var. *Maculatum* grows in woods and is a competitor with the above. The purple color of the flower renders it more attractive. The *E. purpureum* competes with *E. perfoliatum*, L. growing in similar places, but is purple flowered.

In yarrow or milfoil (*Achillea millefolium*) the white heads are attractive to insects. A single flower is small and inconspicuous, but many of these small flowers are crowded together in one head, and in addition the white ray-flowers certainly render them conspicuous. The nectar is easily reached by many insects. It is secreted by a small disc at the base of the style. The flowers are strongly proterandrous. Each flower has five stamens. The anthers are united, and when the flower opens the two divisions of the style are closely appressed in a cylinder made by the five anthers.

The anthers when mature, shed their pollen into the hollow cylinder. The tips of the lobes of the style are furnished

FIG. 27.

Fig. 27, Yarrow (*Achillea millefolium*); 1, head from above; a, stigmas; b, stigmas of disk flowers; c, anther cylinders in their first stage; d, about to open; 2, flower of disk just opening; e, ovary; f, nectary; g, style; h, tube of the corolla; i, filaments; k, two divisions of the style; m, anther cylinder; 3, disk flower pollen issuing; 4, older disk flowers; 5, tip of style of a disk flower, first male stage; r, stigmatic papillae; s, sweeping hair; p, pollen grains; 6-8, *Chrysanthemum leucanthemum*; 6, disk flower (male stage); 8, tip of one stigmatic branch seen from inner side. (After Hermann Mueller).

with hair and as the style elongates it brushes the pollen out

with remains attached to the hairs. When older, these branches turn back and an insect going to a flower cannot but help get some pollen on its body, and as it goes to another flower it is almost certain to leave some pollen on the stigma. While cross-pollination is almost certain to occur, self-pollination and self-fertilization may also occur.

Golden-rod. (*Solidago speciosa*, Nutt). The flowers are yellow, otherwise characters much the same, as in yarrow. It is visited by the following insects: Hymenoptera — *Apidae*: *Bombus Virginicus*, sucking honey *Apis mellifica* sucking honey (quite abundant.) *Halictus coriaceus*, *Augochloro pura*, *Cilissa Americana*, *Caliopsis andreniformis*. *Sphegidae*: *Crabro* sp. *Ammophila conditor*. *Ichneumonidae*: *Trpphon* sp. *Lana montana* (?) *optera Meloidae*: *Epicauta pennsylvanica* feeding on pollen. Hemiptera—*Phymata wolfii*. *Diptera*—*Muscidae*: *Stomoxys*. *Mesograpta marginata*.

Sunflower. The flowers are collected in heads and are made attractive because of the large yellow rays flowers. Like yarrow they are proterandrous. At Ames they are visited by Lepidoptera—*Chrysophanus thoe*. *Diptera*—*Bombylidae*: *Bombylius*. Hymenoptera—*Apidae*: *Nomada luteola*, gathering honey. *Halictus Leronxii*. *Mellissodes perplexa*, gathering pollen and sucking honey. *Vespidae*: *Odyneris foraminatus*.

Bull Thistle. Bull thistle is common in pastures and is rendered conspicuous because the purple flowers are collected in heads. It is strongly proterandrous. In the first stage a large quantity of pollen is pushed out by the style from the opening of the syngenesious anthers. When the style occurs outside of the anther tube a bunch of hairs may be seen as brush hairs. These not only help to take out

pollen but prevents it from falling to the bottom of the tube. The pollen grains are spiny which causes them to adhere not only to the insect but to the hairs on the style as well. The slightly swollen anthers show spontaneous movements and because of the shortening a mass of pollen is thrown out. This happens when an insect seeks the nectar which is secreted by a ring surrounding the base of the tubular corolla, as it is in all other Compositae. In the later stage the pistil has protruded showing the stigma. If the pollen has not been carried away by the insect self-pollination may occur.

Bull thistle, flowers with us from the latter part of July to September and is visited by many worker bumble bees. Mr. Weed says: "But they are not the large and handsome bees found on the *Arbutus* in May, they are much smaller in size and less attractive in appearance. The large specimens which appear in spring are the hibernating females or queens. In addition to bees many Diptera occur, especially syrphus flies, *Lepidoptera*. The *Colias philodice* as well as *Pieris*, *Danaus archippus* and *Papilio turnus* visit the thistle flowers.

Our native *Cnicus lanceolatus*, var. *discolor* is equally interesting.

Dandelion. In *Taraxacum officinale* the numerous flowers are collected in a head. All of the flowers of the head are alike and bright yellow. The head is open in bright sunlight of the early morning and partially closed about noon. When fertilized the "flower stem" contracts, ripens its "seed", and elongates when ripe, so that the "seed" may be distributed. An abundance of nectar is produced which rises up for a considerable distance in the tube, making it accessible to many insect visitors with short tongues. The honey bee is a very common visitor as are also species

of *Bombus*. Many *Diptera*, Syrphus flies, visit it. Mueller records 67 *Apidae*, 7 *Lepidoptera*, 25 *Diptera* and 16 other insects. In the Alps *Lepidoptera* preponderated over the *Apidae*.

Lobeliaceae. Cardinal Flower. *Lobelia cardinalis* L. is common in the eastern part of the state, and

Fig. 28. Proterandrous flowers. 1, *Aster alpinus* part of a head, ray flower partly cut off, disk flowers shown in center with protruding styles; 2, two lobed style of aster showing stigmatic lobes with brush hairs on tip; 4, 5, 6 and 7, flowers of *Centaurea montana*; 7, the lobes of style curved back touching stigmatic lobes; 8 and 9, *Campanula persicifolia*; 8, earlier stage; 9, lobes of style curved back touching hairs on style; 10 and 11, *Phyteuma orbiculare*. Stamens surrounding the style of the younger flower. (After Kerner von Marilaun).

not infrequent in low grounds in central Iowa. The irregular flowers are deep red; the tube is straight and split down on the upper side. The lower lip is spreading, three cleft. Trelease observed that the humming bird, *Trochilus colubris*, visits this species and Robertson says he has never failed to find them about the flowers. He says: "The pendant lip shows that the flower is intended to be visited by a bird or insect which is in the habit of sucking the sweets from flowers without resting upon them. I have also seen the flower visited by *Papilio philenor* L. and *P. trocillus* L."

In *Campanula rotundifolia* the nectar
Campanulaceae. is secreted by a yellow disk which surrounds the base of the style. It is covered by the bases of five stamens. The interspaces are occupied by hairs, thus protecting the honey from unbidden guests. In the bud the three stigmas come together and form a cylinder, the outer surface of which is covered with hairs. Before the flower has opened the anthers are placed around the style.

The stamens dehisce and pollen falls on the hairs of the style. When the stamens have dehisced they shrivel up, the style lengthens out and the flower opens, it is then thickly covered with pollen. When an insect visits the flower takes off some of the pollen, the hairs on the brush shrivel and now the three divisions of the style expand and curve backward. An insect coming from a younger flower will leave pollen on the stigma. The flowers are therefore proterandrous.

In the related *Specularia perfoliata* the early flowers are cleistogamous.

Ericaceae. Laurel (*Kalmia latifolia*) a near relative

of *Rhododendron*, discharges its pollen through a small orifice at the apex of each cell. "In the flower bud each of the ten anthers is lodged in a small cavity or pocket of the corolla." When the corolla expands the filaments are curved outward and backward, and when the flowers are shaken by bumble-bees, which search the flowers for nectar in the bottom of the flower, one after another of its stamens are liberated. The pollen is thrown on the underside of the insect's body.

Some of the other members of the order have interesting contrivances for the dispersal of pollen. In *Vaccinium* the anthers are suspended inside the corolla with pores downward, a shake causes the pollen to issue down on the insect's body. In Winter Green (*Pyrola secunda*) the filaments are curved like a letter S and are in a state of tension, the anthers are in an erect position. When an insect touches the petals the anthers are turned and in the meantime the pollen is turned out.

Primulaceae. Persoon, in 1794, observed that the Cowslip (*Primula veris* var. *officinalis*) existed under two forms. Some most interesting experiments have been made since that time. Darwin called attention to the adaption for cross-pollination. He demonstrated that the pollen of the short stamen, put on the long style of the same flower, is inoperative. The same is true of the pollen from long stamens when placed on the long style of the same. These experiments were later repeated by Hildebrand and John Scott.

In *Primula elatior* two kinds of flowers occur on different plants. One plant bears a long style with short stamens, in which self-pollination is impossible; a second plant bears a short style and long stamens. In this the

pollen can easily fall on the stigma, but Darwin and others have shown that the pollen is quite inactive on its own stigma. There is another important difference. The pollen grain of the long-styled flowers is smaller, while the stigma

FIG. 29.

Fig. 29. Cowslip (*Primula*). Left hand figure, long-styled flower; right hand figure, short-styled flower; a, stamens; co, corolla; st, style. Pollen grains between. The smaller belonging to long-styled flower; the larger to short-styled flower; magnified about 250 times. (After Lubbock.)

is larger. The pollen grains of the short-styled flowers are larger, while the stigmas are smaller. Insects carry the pollen from the short-styled flowers and leave it on the long-styled, while the pollen from the long is carried over to the short.

Darwin notes that in *Primula veris* the corollas of the two forms are different. He sums up the difference as follows: "The long-styled plants have a much longer pistil, with a gobular and much rougher stigma, standing high above the anthers. The stamens are short; the grains of pollen smaller and oblong in shape. The upper half of the tube of the corolla is more expanded. The number of seeds produced is smaller and the ovules larger.

The short-styled plants have a shorter pistil, half the length of the tube of the corolla, with a smooth depressed stigma standing beneath the anthers. The stamens are long;

the grains of pollen are spherical and larger. The tube of the corolla is of uniform size except close to the upper end. The number of seeds produced is larger." He also notes that the short-styled form is more fertile.

Mueller records many visitors such as *Apis mellifica*, *Bombus hortorum*, while *B. terrestris* perforates; *Diptera* (*Bombylius*).

Steironema lanceolatum Gray. is common in low grounds. It is from ten inches to two feet high and has yellow flowers with purple centers. Robertson gives the following account of its pollination: "The flowers look outward and a little downward. In the bud each corolla lobe enfolds an anther. When the flower expands, the lobes carry the enclosed anthers with them, holding them while the stigma is receptive and is exposed to insects—a fact to which my attention was first called by Professor Pammel. After the anthers are released, the styles are commonly found bent outwardly out of the way of the fallen polling. Sprengel supposed that the flowers of *Lysimachia quadrifolia* were nectar-bearing, but failed to find nectar. He, and Mueller also, failed to find honey in flowers of *L. vulgaris*. According to Kirschner, nectar is wanting in *L. nemorum* as well as in *L. nummularia*. I have been uncertain in regard to the occurrence of honey in *Steironema*, but the visits of male bees seem to indicate its presence, although these insects might search for it in vain. They commonly fly about the flowers to find the females, not trying to find honey."

Oleaceae. Lilac. The common lilac (*Syringa vulgaris*) as well as the Persian (*S. Persica*) are common objects of cultivation. The flowers are borne in large, loose panicles, conspicuous because of the lilac color and the strong odor. The two stamens block the tube of the corol-

la, effectively sheltering the nectar, which is secreted by the ovary and occupies the lower part of the tube. The length of the tube prevents short-tongued insects from getting the nectar. Mueller thinks the honey bee can obtain only a part of the nectar. The stamens and pistil mature at the same time. An insect in sucking the nectar first comes in contact with the pollen, then with the stigma which is inserted lower down. Pollen does not adhere to a dry surface but must be moistened with nectar. Self-pollination takes place in the absence of cross-pollination.

Asclepiadaceae. The Milkweeds are as interesting in their adaptations as are the orchids.

Common Milkweed. Hildebrand and Mueller long ago called attention to the adaptations in this flower (*Asclepias cornuti*.) The deeply five parted corolla is of purple color.

FIG. 30.

Fig. 30. Milkweed. Pollinia of *Asclepias cornuti*; 2, flower more magnified with some parts removed.

Next to the corolla is a crown of five hooded bodies seated on the stamens. The five stamens are attached to the corolla, the filaments are united in a tube which encloses the pistil, and the anthers adhere to the stigma. Unlike the pollen of orchids, milkweed always has a pair of pollinia. They are pear shaped and of yellow waxy appearance. They hang by a curved stalk from a dark colored disc. These pollen masses are taken out by insects as they suck the nectar from the glands. The pollinia are attached to the insect's hairs, legs and tongue. Charles Robertson, in an excellent account of plants belonging to this family, finds that

FIG. 31.

Fig. 31. Milkweed. Pollinia of *Asclepias cornuti*; 1. flower as seen from the side; 2. cross section of flowers; 3. pollinia; 4. foot of insect with pollinia. (After Kerner von Marilaun.)

FIG. 32.

Fig. 32. Bumble bee (*Bombus scutellaris* Cress) with pollinia from milkweed (*Acerates longifolia*). (After Charles Robertson.)

in *Asclepias verticillata* the pollinia are usually attached to hairs of insects. In *Asclepias cornuti* the pollinia are more frequently attached to the claws. It is dangerous for small insects to extract the pollinia and insert them into the stigmatic chamber. In one day Mr. Robertson picked thirty-four dead hive bees from flowers. The feet become entangled with the pollen masses. In another species, *A. sullivantii*, he states that in a small patch bearing fifty-two follicles one hundred and forty-seven dead bees were found. In a single umbel he has often found four, and in one case seven dead hive-bees. The insects pollinating these flowers belong to the bees (*Hymenoptera*), butterflies and moths (*Lepidoptera*), flies (*Diptera*), a few *Coleoptera* and *Hemiptera*. Some of these visitors are useless since they do not light on the flower. Others cannot extract the pollinia. Humming birds have been observed, but Mr. Robertson thinks they are useless.

The Gentians are among the prettiest of our autumn flowers. Most of the species in Central Iowa have blue flowers, *G. quinquefolia* L., and *G. Andrewsii*, Griseb. but *G. flavida*, Gray has white flowers.

The *G. Andrewsii* Griseb., which we may take as a type, grows in clumps in marshes and has a blue corolla which is closed at the mouth, with toothed appendages. The flowers are proterandrous. The stamens are united with the corolla tube and the free ends occur over the pistil. Bumble bees in search of nectar must possess a tongue 15-16 mm. long, which must be thrust between the filaments. In speaking of the protection, Mr. Robertson says:

‘There is no doubt that flowers were originally of such a form that almost any insect could enter them and reach the nectar. Many have narrowed the entrance by the develop-

ment of tufts of hair, or of processes like the palates of personae flowers, until all insects were excluded except bees. These have kept on visiting the flowers until now they enter completely closed flowers like those of *Linaria*." Weed observes that owing to a change in color, the bee is able to select the younger nectar-bearing flowers. In our *Gentiana quinquefolia* Lam. the corolla is funnel form and open with a row of conspicuous glands between the bases of the filaments.

Polemoniaceae. Sweet William. The common cultivated

Phlox maculata L. bears numerous purple flowers in an ample panicle. It has a pleasant odor and is frequently pollinated by species of Sphinx. The related *P. paniculata* is proterandrous, according to Mueller.

Borraginaceae. Many of the *Borraginaceae* are adapted to short-tongued visitors, as in *Myosotis*; others are adapted to long-tongued insects, as in *Mertensia*, *Lithospermum*, etc. These are adapted to long-tongued bees and are also visited by Lepidoptera. The colors of the flowers vary from the yellow of the puccoons and blue of *Mertensia* to the white and blue of *Myosotis*.

In *Lithospermum canescens* the flowers are diptogamous or very variable. The *L. angustifolium* produces long, tubular, conspicuous flowers in early spring but as the season advances they become gradually shorter and are finally cleistogamous.

Symphytum officinale L. Common Comfrey produces a tubular, five-toothed corolla, inflated above. The throat is closed by five small scales which probably serve to compel the insect to thrust its proboscis between the proximately closed anthers and to bar out useless visitors. The stigmas and stamens mature at the same time.

Common Borage. The blue flowers of *Borrago officialis* are commonly visited by honey bees which seek the nectar that is abundantly secreted by the pale yellow fleshy part at the base of the ovary. The anthers meet to form a cone.

Mertensia Virginica DC. Blue Bells are conspicuous in deep, rich woods. The blue, trumpet-shaped corolla has a spreading limb; the slender filament are exserted. An abundance of nectar is secreted by four glands at the base of the ovary which alternate with the base of the carpels. Mr. Robertson says: "The blue color and the size of the tube, together with the pendulous position of the flowers, indicate an adaptation to the larger bees, but butterflies sometimes hang on the flowers and draw out their honey. In the following list all the insects are intruders except *Bombus*, *Anthophora*, and *Synhalonia*."

Plants of this order are not abundant in **Convolvulaceae.** Iowa. Most abundant is the common (Morning Glory *Convolvulus sepium*.) The flowers are large and white. It is without odor nor has it any path-finders. It opens during the early morning and is not abundantly visited by insects. Hermann Mueller states that on dark evenings he found it closed between 9 and 10 o'clock, but open on moonlight evenings. Its distribution in Europe is supposed to be dependant on *Sphinx Convolvuli* but Mueller records a number of other visitors and Robertson reports a number of *Apidae*.

The *C. arvensis* has become a common weed in places. It has a funnel-shaped, white or red corolla with a yellow base on the inside and five radiating white streaks which are the path-finders. The flower closes in the evening and rainy weather and is therefore adapted to diurnal insects.

The *Ipomoea testigridis* L. has cleistogamous flowers. This is said to be true also of some members of the genus *Cuscuta*. The *I. batatas*, or Sweet Potato, seldom flowers.

The members of this order are adapted to a various class of visitors. The large-flowered species of *Datura* are adapted to *Sphingidae* and especially to the humming bird. In *Solanum tuberosum* and *S. nigrum* the flowers do not secrete nectar but are visited solely for their pollen. In *S. tuberosum* the five anthers meet to form a cone and surround the style. The anthers begin to dehisce at their apex and when touched the pollen falls out. Mr. Robertson has observed females of *Bombus americanorum* collecting the pollen.

Datura Stramonium. The Jamestown Weed is a tall coarse weed with a white corolla about three inches long and

FIG. 33.

Fig. 33. II. *Datura* flower visited by humming bird; three-fourths natural size. Left hand figure. *Heiothrix aurita*, three-fourths natural size. Right hand figure. *Heliactinus cornutus*, three-fourths natural size. I. Sword beak *Docimastes ensifer*. (After Brehm. from Behrens' text book.)

stamens adherent to the corolla tube for a part of the distance then leading inwards, thus effectually excluding bees from the honey so that only Sphingidae can obtain it. Mr. Robertson reports that honey bees remove the pollen as soon as the flower is open, before the flight of *Deilephila lineata*. A Venezuelan species of *Datura* is visited by *Docimastes ensifer*, the female of which has a beak 8 cm. long, and the male one 10 cm. in length, these corresponding to the tube of the corolla.

Nicotiana glauca. This commonly cultivated plant is clammy pubescent with a large white corolla, a long and nearly cylindrical tube, 5-6 cm. long, with a limb deeply five cleft. The stamens are inserted on the tube and included; the stigma partially blocks the passage way. The flowers are open during the night and are delightfully fragrant. Here at Ames it is abundantly visited by *Sphingidae*.

Schizanthus pinnatus. This plant is now commonly cultivated in gardens. Its flowers are irregular, two-lipped. The upper lip is made up of five parts, variously colored and spotted with yellow and purple, a narrow groove leads to the nectar. The under lobe of the smaller lip is more or less hooded and sack-like. When the insect settles upon the lower lip it springs up and the pollen is thrown out for a considerable distance. The stamens are held in the tube of the lower lip.

Schrophulariaceae. The members of this order show various adaptations to insect visitors. Some of the species have corollas regular or nearly so, as in *Veronica*. These are adapted to flies and bees. Secondly in *Scrophularia*, the flowers are dull in color with a wide open mouth and nectar easily accessible and *Antirrhinum* and *Linaria* with the nectar protected, pollinated by large bees.

In *Pedicularis* the tubes are narrow; the upper lip protects the anthers while the lower lip serves as a landing place. As to colors the flowers are various, even in closely related species of the same genus, as in *Pedicularis* and especially in *Castilleja*.

Scrophularia nodosa L. var. *Marilandica* Gray. Prof. Trelease has given us an interesting account of the pollination of this plant. It is especially adapted to wasps. Mueller records 6 *Vespidae*. He says: "The fact that they hold a proportion of over one-third in the list of *Scrophularia* is sufficient evidence that the flower especially favors wasps. I know of no bee-flower on which so many wasps occur as intruders." It is frequently visited by hive-bees.

The small, greenish-purple, irregular flowers are proterogynous. In its earlier stages the stigma only protrudes, it

FIG. 34.

Fig. 34. *Scrophularia nodosa* var. *Marilandica*. 420, 421, early flower pistil mature. 422, flower a day or two later, pistil flabby, stamens mature. (After Gray).

is inclined over the lobe. Honey bees and wasps which largely pollinate the flowers, approach them from the front, come in contact with the stigma leaving some of the pollen on it. The following day the stamens come in view and the style becomes flabby and rests on the lower lip. An insect

in going to the flower for the nectar is dusted with pollen from the later flowers. Self-pollination cannot occur.

Snap dragon (*Antirrhinum majus*). The flowers are borne in a raceme and the purple, brown and yellow corollas are very conspicuous. It is pollinated by bumble bees that are sufficiently strong to force the upper lip back. The honey is secreted at the base of the ovary.

This plant differs from common Toadflax in its much larger flowers into which bumble bees can enter bodily, and also by its firmly closed corolla which excludes the smaller bees. The nectar is secreted by the smooth, green fleshy base of the ovary.

The Yellow Rattle (*Rhinanthus crista galli*, L.) which occurs along the New England coast, in the mountains of New Hampshire, Lake Superior region and northward sheds its

FIG. 35.

Fig. 35. Debiscence of anthers. 4, anthers not separated; 5, single anther; 7, and 8, *Pyrola secunda* showing position of stamens and in the latter how pollen is shed. The dagger in each case indicates how the insect enters the flower. (After Kerner von Marilaun.)

pollen in an interesting way on the insect's head. "Each

anther lies so close to its opposite neighbor and they dehisce so widely on their opposed faces that both together form one pollen reservoir." They are closed together by the hairs on the edges of the anthers. The filaments are rigid. At their bases the anterior pair is set close together and provided with sharp points on their inner sides but a short distance below the anthers they are smooth and wide enough apart to admit the head of an insect. When the bee's tongue is pushed in, the filaments are forced apart, the anther cells are torn and the pollen falls on the insect.

Yellow Rattle produces two kinds of flowers, one conspicuous and unable to be self-fertilized, the other conspicuous and regularly self-fertilized.

Labiatae. For a general synopsis of the *Labiatae*, a paper by Robertson and Hermann Mueller's Fertilization of Flowers should be consulted. Robertson says:

"In the case of the *Umbelliferae*, which have very uniform flowers, I have been able to show that the preponderance of the bees, lower *Hymenoptera* or *Diptera* was determined mainly by the time of blooming, and the peculiarities in the lists of visitors were best shown by a table arranging species in the order of blooming. A similar arrangement of the *Labiatae* does not give very important results, since the differences in the lists are mainly due to differences in structure, and the time of blooming has little influence. In the case of the *Pycnanthemums*, there seems to be a plain case of correlation between the form and arrangement of the flowers and the time of flight of the lower *Hymenoptera*, which are very important visitors. If the flowers bloomed in April the lower *Hymenoptera* would be almost entirely wanting, and the list would consist mainly of bees and flies.

Of the twenty-three species considered in the present

paper nine show long-tongued bees—*Bombus*, *Synhalonia*, *Anthophora* and *Melissodes* — as their principal visitors and depend mainly upon them. Eight show special adaptation to bees in general or to shorter-tongued species. Early

FIG. 36.

Fig. 36. Sage (*Salvia glutinosa*). 1 and 2, visited by bumble-bees. 2, style touching thorax. 1, Anthers touching insect. 3, stamen with long connective, which connects the sterile anther lying in front of the opening of the tube of the corolla, and the fertile anther lying in the arched upper lip. In 4 and 5, the dagger indicates the point where the insect strikes the hinged sterile anther. (After Kerner von Marilaun.)

blooming species are visited by *Bombus* females, *Anthophora*, *Synhalonia*, *Osmia* and *Alcidamea*. Later blooming species are visited by *Bombus* males and workers and *Melissodes*, while bees of the other genera are wanting."

Sage. As previously stated, irregularity is one of the causes that leads to cross-pollination by insects. One of the most interesting is the pollination in meadow sage (*Salvia pratensis*) which was accurately described and figured by Sprengel. The flowers in this species, as Hildebrand has shown, are proterandrous. This pretty blue sage is common in the meadows of Europe. The blue labiate flowers are arranged in a raceme. The upper lip is arched. In their first stage the stigmas are folded together and protrude from the upper lip but later they unfold and point downward. The opening of the tube of the corolla is guarded by two oblique processes which are the sterile, transformed anthers. Attached to these are extremely long connectives. (In most flowers the connective between anther cells is short). The other anther cell is under the arched lip of the corolla. Now, when a bumble-bee lights on the under lip and thrusts its proboscis downward into the nectary which is indicated by the purplish spot, it comes in contact with the processes which close the throat of the corolla. When they are touched they lift upward and backward and the fertil anthers concealed under the arched upper lip come forward and downward, and in this way the pollen is brushed off on the bee's back. The bee gets an abundance of nectar which is found in the lower part of the tube, and secreted by the yellow, fleshy portion underneath the ovary.

In *S. lanceolata*, which has become not uncommon in some parts of Iowa, the blue flowers are conspicuous. The lip forms a landing place for insects. The style extends be-

yond the upper lip and is curved up and the anthers have the same adaptation as in other species. The connective blocks the passage way and as the insect thrusts its proboscis into the flower the other anther comes over its back.

Salvia sclarea, *S. aethiopica*, and *S. glutinosa* have a similar arrangement for pollination. When the insect visits an older salvia flower and is about to enter, some of the pollen is left on the stigma. Figure 33 pg. 88 shows an excellent likeness of *Salvia glutinosa*. In *lopezias* (*Lopezia coronata*, etc.) the pollen comes to the insect from the lower side. While some of the salvias are adapted to bumble-bees for pollination, Prof. Trelease has shown that *Salvia splendens* and others are pollinated by humming-birds. The color of *Salvia gesnerifolia* is brilliant. Bees cannot get nectar in the normal way. *Lepidoptera*, though having a tongue sufficiently long to get the nectar cannot do so, owing to the lower ends of the connective, which are dilated. The levers are stiff enough to prevent butterflies from working it.

Nepeta Cataria. In catnip the flowers are born in glomerate cymes and are proterandrous. The short corollas are whitish and spotted. The nectar is accessible to many short-tongued insects. It is commonly visited by the honey bee and some species of *Bombus* as well as some *Diptera* and *Lepidoptera*.

Monarda fistulosa. Horse Mint is a common plant, growing in our woods and along railroads. It is quite conspicuous with numerous branches and flowers in glomerate heads. The bilabiate corolla is pubescent; the upper lip is narrow and extends obliquely upwards, containing the stamens and pistil, the former being attached to the lower lip of the corolla. Since the anthers and stigma are so far apart the largest bees are likely only to touch them when landing

upon it. The nectar is secreted by the fleshy disc below the ovary and is protected from unbidden guests by small projections. Mr. Robertson, in speaking of the flower, says.

"The tubes measure 18 to 19 mm., which indicates an adaptation to long tongues. The form of the tube, the bilabiate corolla, and the position of the stamens and style indicate that the flower is a modification of a *nototribe* flower originally adapted to bumble-bees. The level-topped heads, the erect corollas, the exposed organs and the rose color indicate a tendency to suit butterflies, which in fact are the principal guests."

Among the insect visitors here at Ames are: *Hymenoptera Bombus virginicus*, *B. pennsylvanicus*, *Odynerus foraminatus* and *Lasius brunneus*; *Diptera*, two species of the family *Bomyplidae*; *Hemiptera*, *Phymatus wolfii*, *Lygus pratensis*, and *Calcoris rapidus*. In Colorado it is much visited by several species of the Genus *Bombus*, also some *Lepidoptera*. In Wyoming where I observed this species this summer *Bombus* is also a frequent visitor. The flowers have a much deeper color especially at an attitude of 5000 feet.

Lamium amplexicaule L. Species of the genus *Lamium* are adapted to bumble-bees. Mueller never succeeded in finding bees in the species here considered. He says; "But I have found immediately after the opening of the flower, the tip of the lower stigma standing not above but below and between the anthers, and dusted with pollen, no doubt from the same flower." The purpose of calling attention to the species here is that the plant has in addition to the ordinary also clesistogamous flowers. Axell was of the opinion that the existence of such flowers in this species was due to a lower tempature which checked the develop-

ment of the conspicuous flowers and also because insects failed to pollinate the flowers during bad weather.

FIG. 37.

Fig. 37. Cleistogamous flower of *Lamium amplexicaule*. (After Lub-
buck).

FIG. 37 A.

Fig. 37 A. Section of cleistogamous flower of dead nettle (*Lamium amplexi-
caule*). (After Lubbuck.)

Aristolochiaceae.

Birthwort (*Aristolochia clematitis*) is an example of flowers pollinated by small flies; the arrangement is quite unique. The yellow flowers are arranged in whorls. The long, tubular flowers consist of a wide, funnel-shaped throat and a long and narrow tube which is lined with stiff hairs. The lower part is enlarged and contains the stamens and part of the pistil. In *Aristolochia ringens* the calyx has developed a lower and upper lip. In the birthwort there is a flattened expansion which serves as a resting place for insects. The colors as well as the disagreeable odor make these flowers attractive to certain kinds of insects. Flies find no difficulty in going into the flower, since the hairs all point in an oblique direction away from the opening. When the insect reaches the expansion it is comfortably housed. The temperature is several degrees warmer than the surrounding air. They now try to escape, and in doing so come in contact with the stigma where they leave some pollen from other flowers, but they cannot es-

cape since the hairs all point in one direction. The flower is a trap and the insects are prisoners for one or more days. Some nourishment is found, but in the course of time the stamens mature and the anthers dehisce and a large amount of the pollen drops on the floor of the cavity. This food is

FIG. 38.

Fig. 38. Bitrhwort (*Aristolochia clematitis*). I. Inflorescence. II. Transverse section before pollination. III. After pollination, s, throat. r, tube h, hairs. r, expansion of tube of calyx. n, stigma. a, anthers. b, ovary. (After Behrens.)

welcomed by the insects but they soon become restless and in their endeavor to escape become dusted with pollen. The time has about arrived for the insects to be liberated. The hairs wither and now the insects can escape; at the same time the peduncle bends over so that the flowers drop. The prisoners escape, go to the younger flower, leave some pollen on the stigma and when the stamens dehisce, after imprisonment, are liberated again.

Elaeagnus angustifolia. This beautiful

Elaeagnaceae. European shrub is related to our north-western Buffalo Berry (*Elaeagnus argentea* Pursh.) It has

perfect flowers. The calyx gamosepalus; the outer part of the tube and the lobes are silvery scurfy, the inner at first greenish yellow, later becoming lemon yellow. The flowers are not conspicuous though the odor is decidedly attractive and pleasant, the air being scented for some distance. Stamens four, somewhat shorter than the pistil, both maturing at the same time. The nectar is secreted from a large fleshy gland at the lower end of the style in the bottom of the calyx tube. It is much visited by the honey-bee and *Bombus*.

The pollination of fig (*Ficus carica*) is just as remarkable as that of the *Yucca*. Since ancient times artificial pollination or caprification was affected by the *Caprificus*. This was done by hanging ripe fruit of the *Caprificus* to the branches of the fig tree "whose figs are then in their female stage with open ostiola." The wasps issue from the *Caprificus*, enter the fig and bring pollen of the former. In order to fully understand the method of pollination we should study the structure of the flowers. A fig is not a single ripened fruit, but a branch in which there are a large number of fruits. In some species as *Ficus pumila* female flowers only occur in the bottom of the urn, while the pollen bearing flowers occur around the opening.

In *Ficus carica* two kinds of plants occur; *Caprificus* which bear on the inner wall a large number of female flowers, which are later formed into galls. The male flowers which line the opening do not mature till the insects are hatched. The second kind only bear figs, *Ficus*. The galls in the *caprificus* are formed in this way. A small chalcid wasp (*Blastophaga grossorum*) enters the urn through the ostiolum and its ovipositor is thrust vertically in the style of the flower. It deposits its eggs in the ovary of the female flowers between the nucleus and the integuments placing one

FIG. 39.

Fig. 39. Transport of pollen by insects laying eggs in ovary. 1, *Yucca* (*Y. Whipplei*). 2, A single opened flower with insect *Pronuba yuccasella*. 3, Stigma of the same. 4, The insect flying to the flower. 5, Head of the *Pronuba* with a ball of pollen from the flower. 6, *Ficus pumila*. 7, A single flower taken from lower part of the urn of the same species. 8-9, Stamens, upper part of the urn. 10, *Ficus carica* (common fig) with galls of *Blastophaga*. 11, Same with fertile flowers showing wasps. 12, Staminate flowers. 13, Pistillate flower with long style. 14, One of the pistils developed into gall. 15, Insect coming from gall. (After Kerner von Marilaun.).

egg, only, in each. The small white larvae grow rapidly and cause the wall of the ovary to develop, and in consequence the seed does not form, but the fruit develops into a gall. When the insects are mature they leave the galls, the wingless male first; the females remain somewhat longer. After leaving the ovary they are fertilized by the male. They do not tarry long in the urn. In going out by way of the ostiolum they come in contact with the pollen which is dusted over their whole body. They allow their wings to dry, and then run to another urn, either on the same plant or another. In entering a new urn their wings are injured or broken off. They leave some of the pollen on the stigmas and when these are in the perfect flowers, seed is developed; but when imperfect, as in those which produce galls, fertilization does not occur. It has been observed that although the insect deposits its eggs in the perfect flowers, in *Ficus carica* they will not develop, since the ovipositor is so short that it cannot reach the ovule. The caprificus becomes hard and withers on the tree, its only use being to produce pollen. The fruit of the fig tree *Ficus* becomes sweet and juicy when the seed ripens. The pollination of all species of *Ficus* have not been studied although for the 600 species described there are at least fifty species of small wasps belong in to the genera *Blastophaga*, *Crossogaster*, *Sycophaga* and *Tetrapus*, which carry pollen from one urn to another. One species, *Blastophaga brasiliensis*, has been found on seven different species of fig tree. Figs will also develop without caprification.

Salicaceae. The willow flower is simple in its structure and is usually dioecious. The anthers of

the staminate flowers usually have some decided color. The flowers are massed in catkins and open out before the leaves

appear, as is usual with anemophilous plants. They have an abundance of nectar, which, in the early flowering periods, leads many insects to go to it. They also have a decided odor. The staminate flowers are more conspicuous than the pistillate, especially in *Salix nigra*.

Each flower consists of a small bract, with the stamens, one or more, to the inside. These are accompanied by one or two small nectar glands. In the pistillate flower the stamens are replaced by the pistil and a nectar gland. The willow is one of the lowest of the entomophilous plants. It is visited by a variety of insects. The honey bee, bumble bee *Andrena*, and other *Hymenoptera* visit it, as also do flies (*Bombylius*), butterflies (*Vanessa*), and beetles. The Andrenas are common visitors; the head and thorax of these insects are provided with hairs and as the insects take the nectar from the staminate flowers the pollen grains adhere to the bristles and then as they go to the pistillate flowers for nectar some of the pollen is left on the stigma. The petioles of some of our willows are provided with glands. *Salix laurifolia* has so many of these glands that the tree has a decided odor. These glands are no doubt for protection.

Orchidaceae. Darwin, in the introduction to his classic work, "On the Fertilization of Orchids by Insects" says: "As orchards are universally acknowledged to rank amongst the most singular and most modified forms in the vegetable kingdom, I have thought that the facts to be given might lead some observers to look more curiously into the habits of our several native species. An examination of their many beautiful contrivances will exalt the whole vegetable kingdom in most persons' estimation."

Earlier Sprengel observed that insects were necessary to

remove the pollen masses, and Waetcher, who seems not to have been acquainted with Sprengel's work, stated that insects are necessary for the pollination of orchids. Orchids have been the objects of a large number of interesting papers. The order is represented by more than three thousand species. Few of our native species compare in beauty with those of the tropics. In habit they are extremely diverse. Hermann Mueller says: "I do not doubt that orchids owe their extraordinarily perfect adaptation to particular insects not only to the tendency of the parts of their flowers to variation, but also to the separation in time of the two stages in the act of impregnation. The extremely complete adaptation to cross-fertilization have in their turn resulted, in many cases, in the flowers becoming absolutely sterile to their own pollen."

It may take days, weeks, or even months for the pollen-tube to reach the ovule and cause impregnation. It may be interesting to observe that the period of flowering as in many cases extended over a considerable length of time.

Orchids differ in regard to their capacity for self fertilization; some have cleistogamous flowers, as in *Cattleya* and *Epidendrum*; some are self-pollinated, or at least occasionally so, frequently in *Neottia nidus-avis*; others are never self-pollinated although when their own pollen is applied artificially it is fertile, while some are absolutely sterile to their own pollen though fertile to pollen from another plant of the same species or to the pollen from a plant of another species. In some cases the pollen of a plant acts as a poison when applied to its own stigma.

In order to fully understand the mechanism for the pollination it will be necessary to give the parts of an orchid flower. The perianth consists of six parts in two sets; the

three outer, known as the sepals, are generally colored. The petals consist of the three parts one of which the upper is larger than the others and occurs on the lower side, this is known as the labellum and is often produced into a spur-like nectary. In front of the labellum occurs the stamen which is united with the pistil. In *Cypripedium* there are two stamens with the rudiment of a third. The anther has two very distinct cells; the pollen coheres in masses, each of which has a stalk; these masses with their stalks are known as the pollinia. In the genus *Cypripedium*, the pollen is granular. The ovary is produced above the perianth and rises up in the middle of the flower as a column. The stigma is broad and lutingous. The rostellum is a modified stigma; a part of this is removed with the pollen masses and is called the viscid disc.

* In *Cypripedium pubescens*, which occurs in rich woods, is offered an interesting object for study. Lady's slipper or moccasin flower, of which there are several species in Iowa, has three spreading sepals; two of them are usually united into one under the lip. The labellum is arranged into a kind of moccasin, hence the common name, Lady's Slipper or Moccasin Flower. The edges are recurved or over-arched. The stamens and pistil are united. We have a peculiar shield-like body which is notched or hollowed out, and two fertile anthers. The pollen is not united in pollina. The surface of the stigma is beset with numerous sharp pointed papillae which are for the purpose of holding the pollen.

Insects are attracted by the color and strong odor and find it an easy matter to get into the flower, but they experience some trouble in getting out the way they entered, since the margin of the lip is rolled in. Prof. Trelease was

the first to call attention to the fact that in some of our *Cypripediums* a portion near the upper end of the inflated sac in transparent, serving as a window. An insect would naturally make for the light, and since this window is near the small opening the insect goes out. It gets some of the pollen on its head as it comes in contact with the varnished

FIG. 40.

Fig 40. 1, European lady's slipper (*Cypripedium calceolus*); on the left hand side an insect, *Andrena* going out of the flower with pollen adhering to its back; 2, sectional side view of same; 3, an *Andrena*. (Kerner von Marilaun).

film of the pollen. Some nectar is found on the hairs in bottom of labellum. Now, when the insect flies to another flower and enters by the large opening, it cannot fail to get some of the pollen from its head, against the large stigma which partially blocks the passage way. Dr. Gray says: "The stigma of every other orchid is smooth and glutinous; this is merely moist and finely roughened; the roughness comes from very minute projections all pointing forward so that the surface may be likened to a wool-card

or rasp." I have observed these windows in several of our species—small white lady's slipper (*Cypripedium candidum*) large yellow (*C. pubescens*) and perhaps also occurring in other species.

Mueller thus describes the insect's method of going out and in: "These bees, attracted by the color and perfume of the flower, fly into the slipper shaped lip and lick and bite the hairs lining its floor, which are sometimes covered with small drops of honey. They try for some time to escape by climbing up the vaulted sides of their prison toward the orifice that they entered by; at last, after creeping beneath the stigma; they manage with a great effort to escape by one of two small lateral openings at the base of the lip; in doing so they smear one shoulder with a sticky pollen from the anther immediately above. In the next flower, the bee, as it creeps under the stigma, leaves some pollen on its papillae, which are long and point obliquely forwards; then, squeezing itself again through one of the small orifices, it acquires another load of pollen; cross-fertilization is thus effected regularly." He found chiefly *Andrena*.

Delpino believes the *C. barbatum* is pollinated by flies and that *C. caudatum* is pollinated by snails. Weed states that he found *Halictus* pollinating flowers of *C. acaule*, the Pink Lady's slipper. The pollination of this species is described by him as follows: "The most striking part of the latter (the blossom) is the pouch-shaped labellum, projecting forwards and downwards. This curiously shaped organ consists of a large inflated sac, with the front edges inflected in such a way as to form a slit-like opening."

"The inside of the bottom of the labellum is furnished with hairs projecting upward and backward. Many of them are tipped with a glutinous secretion, which is believed to be

eaten by the insect visitors. No other signs of nectar are to be seen."

"Sometimes one will find a dead bumble bee in the Moccasin flower. It has gone in through the large opening of the labellum, has been unable to escape the way it came, and crawling upward, becomes imprisoned beneath the stigma, where it finally dies."

Greater Green Orchis (Habenaria orbiculata).—Dr. Gray gives the following account of the pollination in this species: The three external parts of the perianth, the sepals, are much broader than the three internal, the petals. The

FIG. 41.

Fig. 41. Hawk moth (*Sphinx drupiferarum*) with two pollinia, one attached to each eye from *Habenaria orbiculata*, as it comes from the flower. The long tongue partially uncoiled. The figure to the right shows the deflexed pollinia and the coiled tongue in the center. (After Gray.)

base of the long and narrow petal is turned downward and hollowed out into a long tube, which is closed at the bottom and open at the top. This is the spur or nectary, and contains the nectar which is secreted in it. The single anther and stigma are united and lie just beyond the opening of the nectary. The anther cells open by a long chink. approach-

ing each others at the upper end, while the lower is widely separated and the space between is very glutinous. The

FIG. 42.

Fig. 42. Flower of *Habenaria orbiculata*, 46, stamen and stigma more magnified; 462, one of the two pollen masses. (After Gray.)

FIG. 42 A.

Fig. 42 A. Pollinia and pollen grains of orchid (*Habenaria orbiculata*). 464, five separate pollen packets; the figure below more magnified, showing pollen grains; the figure to the left shows a pollen mass and stalk, at the base a gland. (After Gray.)

pollen grains are united by fine threads, then into larger, finally forming pellets, and having a stalk attached to a central stalk. At the lower end of this stalk is attached a button-shaped disc, the face of which is exposed and is on a line with the surface of the anther, so that these two discs look toward each other across the broad, intervening stigmatic space. When a finger or any small body touches these discs they adhere so firmly that the attached pollinia or pollen masses are dragged out of the cell and carried away entire. When a hawk-moth like *Sphinx drupifearum* visits these flowers and presses its head into the center of the flower to get the nectar out of the nectary a pollen mass will be fixed to each eye, and on withdrawal these will stand as shown in figure.

But they are soon turned downward as shown to the right. This is due not to their own weight but to a contraction in the drying of one side of the fleshy piece which connects the disc with the stalk. When the moth passes from one flower to that of another plant, and thrusts its proboscis down to get the nectar the pollen masses on the insect will be brought in contact with the large viscid stigma; either some of the pellets will be left on the stigma or a whole pollen mass."

Cata setum. This is interesting as regards its pollination. It is not uncommon now in greenhouses. Its remarkable adoption was first pointed out by Darwin. In this orchid the pollina and stigmas are in different flowers. Like *Habenaria* the pollinum is furnished with a viscid disc, but in this case the insect does not touch the viscid disc. The flower is sensitive and throws the pollinium at the insect. Sir John Lubbock says that Darwin irritated one of the flowers in his presence and the pollinium was thrown nearly three feet. In a staminate flower the pollinium, which is in a state of

FIG. 44.

Fig. 44. *Catasetum* section; po, pollinium; an, antennae; d, viscid disk, (After Darwin.)

FIG. 43.

Fig. 43. *Catasetum*; an, antennae; l, labellum; po, pollinium. (After Darwin.)

tenison, is curved, and held in a position by a delicate membrane. Insects light on the lower lip of the flower. In front of this lip are two processes known as antennae. In *Catasetum saccatum* only one arm is sensitive; in some species both are sensitive. When the insect touches the left hand one, the excitement is conveyed along it, the membrane retaining the pollinium is ruptured, the latter released and thrown with considerable force with the viscid disc foremost, and in such a direction as to come in contact with the head of the insect. When the insect visits another plant containing the pistil it leaves some of the pollen on the stigma.

The *Angraecum sesquipedale* is a native of Madagascar. The spur in this species is longer than of any other orchid. It varies from 10 to over 14 inches in length. It is said, according to Darwin, than an insect must have a tongue 11 to 12 inches long in order to reach the nectar.

Darwin, in the following words, says: "It is, however, surprising that any insect should be able to reach the nectar. Our English Sphinxes have proboscides as long as their bodies; but in Madagascar their must be moths with proboscides capable of extension to a length of between 10 and 11 inches. This belief of mine has been ridiculed by some entomologists, but we now know from Fritz Mueller that there is a sphinx-moth in South Brazil which has a procoscis of nearly sufficient length, for when dried it was between ten and eleven inches long. When not protruded it is coiled up into a spiral of at least twenty windings."

Mr. Forbes has found a moth in Madagascar with a tongue long enough to reach the nectar.

A green, whip-like nectary hangs down beneath the labellum. According to Darwin only the lower one and one-half inches, in the species he examined, as filled with nectar.

I have seen some that were between 12 and 14 inches in length.

Spiranthes. Flowers white and very fragrant. The parts of the perianth are so disposed as to limit insects from obtaining the nectar. Mr. Robertson describes it for *Spiranthes gracilis* as follows: "The upper sepal is connivent with the two upper petals, forming the upper wall of the tube. At the free end these part from a three-toothed upper lip. This is too small to form a landing place for insects, but makes the flower a little more conspicuous. A proboscis about four millimeters long can drain the nectar with ease. At Orlando, Florida, I saw them visited by a bee which I failed to capture, but which I supposed was *Anthidium notatum*, Latr., and by *Megachile brevis* Say.

The last mentioned insects had two discs with attached pollinia fastened to the maxillary laminae, and I think this is the particular part of a bee to which the flower is adapted to fasten its pollinia.

But the most important consideration is that when the bee's proboscis is folded up under the head, the maxillary laminae fall into such a position that the pollinia retain their hold without danger of being disturbed."

Iridaceae. In the Flower-de-Luce (*Iris versicolor*, L) the perianth is made up of six parts of violet blue color and purple-veined. The three outer divisions are reflexed; the three inner are smaller and erect. There are three stamens, one on each side of the stigma; back of each stamen and partly overhanging it is a peculiar petal-like body—the style, the stigma occurs as a thin lip under the apex. Stigma and stamens are protected; the former is larger than the latter; the anther discharges its pollen through a long opening away from the stigma. An insect alights on the ex-

panded petal and, guided by the hairs, obtains the nectar, and in doing so brushes against the stigma where it leaves some of the pollen, from another flower. It is visited by bumble bees, *Syrphus* flies, also butterflies, which, however are not normal pollinators.

Liliaceae. The order is separated into several very distinct groups; in some the nectar is easily accessible, others, as the tulips, are without nectar. Species of *Allium* are visited by a miscellaneous lot of visitors. *Lilium* with a

FIG. 45.

Fig. 45. *Pronuba*, from larva to adult. (After Riley).

narrow groove is adapted to *Lepidoptera*, nocturnal and diurnal.

Wild Yellow Lily. The *Lilium Canadensis*, L., is common in our northern swamps. The flowers are pendulous, the perianth consists of six parts, yellowish-orange with brown spots. The nectary occurs in the form of a groove in the middle of each division of the perianth. The six stamens have their linear anthers extrorsely attached near the middle finally becoming versatile. The style is elongated and somewhat club shaped; the stigma three lobed. It is pollinated by Hymenoptera. Mr. Weed records *Megachile*, but I have observed *Trochilus*. The *Lilium Mortagon* is pollinated by *Sphingidae*.

Yucca. The glorious yuccas are native American plants occurring most commonly in the dry, sandy regions of the southwest. Spanish dagger or Spanish bayonet (*Yucca angustifolia*) occurs in the loess region on the Missouri river in the western part of Iowa. Drs. C. V. Riley and George Engleman have made some interesting and valuable observations on the method of pollination in this species. Prof. Trelease and Mr. Webber have substantiated their work. In Yuccas the relation between the flower and a yucca moth is very close. The pendant, more or less bell shaped flowers are borne in mostly simple racemes having a perianth of three sepals and three petals, yellowish white in color and very fragrant. Both color and odor make them conspicuous for

FIG. 46.

Fig. 46. Moth collecting pollen. (After Riley).

night-flying insects. The viscid pollen is contained in small anthers which arise from the papillose, curved filaments. A

flower remains open for a single day, on the second day the ends of the six stamens begin to close up and the flower has the shape of a balloon with six small openings. At twilight and during the night, there is flying about the flowers of the yucca a yellowish white moth with a metallic luster, the *Pronuba yuccasella*. The first joint of the maxillae is extraordinarily lengthened, and on the inner side it is provided with stiff bristles. It can be rolled up as a proboscis. This structure is for the purpose of collecting, rolling up and holding

FIG. 48.

Fig. 48. Moth with a ball of pollen. (After Riley).

the pollen. The females of the moth enter the open flower and obtain the pollen, not however to eat, but to carry it to another flower. In a short time the moth has col-

lected a ball of pollen which it holds on the under side of the head by the maxillae. It appears like a large craw. It is sometimes three times as large as the head of the insect. It immediately leaves the flower to search another. It now deposits its eggs in the side of the ovary. The ovipositor consists of four horny bristles pressed together which is well adapted for boring the tissues of the ovary. After the eggs are deposited the moth runs to the hollow funnel shaped stigma, she then rolls up her proboscis-like mandibles and places the pollen on the stigmas. The eggs hatch on the fourth or fifth day. Each larva requires from 18 to 20 seeds for its development. When mature it bites a hole through the fleshy wall and reaches the ground by means of a thread, enters the soil and forms an egg shaped cocoon. It remains in this stage till the following summer. About fourteen days before the flowering time of yucca it pupates and when the flowers open, tiny moths issue from the pupa. The pollination of yucca is an extraordinary case. Without the yucca moth the viscid pollen could not reach the stigma. If the yucca moth is excluded seed will not develop. *Yucca angustifolia* and *Y. Whipplei*, when grown in Europe have never developed a single seed.

Dr. Riley says: "Upon a superficial view this little moth shows nothing very peculiar. The general coloration is white, the primaries being purely white on the upper surface, so that when at rest in the half-open flowers of the Yucca it is not easily detected. The under surfaces, however, are dusky and offset in flight the whiteness of the rest of the body, so as to render the species somewhat difficult of detection while flitting from plant to plant. The male shows no very marked peculiarities to distinguish it from the other members of the family, the most noticeable being,

perhaps, the prominence of the exposed portions of the genitalia. The female, however, shows some remarkable structural peculiarities, which admirably adapt her for the functions she has to perform, for she must fertilize the plant, for her larvæ feed upon the seeds."

"Her activity begins soon after dark, but consists, at first, in assiduously collecting a load of pollen. She may be seen running up to the top of one of the stamens and bending her head down over the anther, stretching the maxillary tentacles, so wonderfully modified for the purpose, to their fullest extent, the tongue uncoiled and reaching to the opposite side of the stamen, while the head is kept close to the anther and moved peculiarly back and forth something as in the motion of a caterpillar when feeding. The maxillary palpi are used in this act very much as the ordinary mandibles are used in other insects, removing or scraping the pollen toward the tentacles. After thus gathering the pollen she raises her head and commences to shape into a little mass or pellet by using her front legs, very much as a cat does when cleansing her mouth, some times using only one leg, at another time both, smoothing and pressing the gathered pollen, the tentacles meanwhile stretching and curving. After collecting all the pollen from one anther she proceeds to another and repeats the operation, then to a third and fourth, after which, with her relatively large load—often twice as large as the head—held firmly against the neck and front trochanters, she usually runs about or flies to another plant; for I have often noticed that oviposition, as a rule, is accomplished in some other flower than that from which the pollen was gathered, and that cross fertilization is thus secured."

Araceae. The Aroids have some interesting points in their pollination. Some of the species are dull in color as our Jack-in the Pulpit.

Aroids. In *Arum maculatum* The "flower" consists of a green leaf called the spathe which contains a central portion, the spadix, that bears the flowers. The pistils are near the base, while the stamens are higher up. Lubbock says: "Now in this case nothing would at first sight seem easier or more natural than that the pollen from the anthers should fall on and fertilize the pistils." In this case the stigmas mature before the pistil — proterogynous. Small flies (several hundred have been found in a single flower), which are attracted by the showy spadix, enter the flower and are imprisoned by the stiff hairs which line the spathe. They have, however, left some pollen on the ripe stigmas. After the period of maturity has passed, each stigma secretes some nectar which repays the insect. The stamens then dehisce, the pollen drops to the bottom of the cavity, and the insects become covered with pollen. The hairs on the spathe now shrivel up and the insects are released. In *Arum conceptaloides* the structure of the inflorescence is somewhat similar. The insects seek shelter in the "flowers," which are somewhat warmer than the surrounding atmosphere — 30° to 36° Cent., while in *Arum Italicum* the temperature has been observed at 44° Cent. The flowers of this and other aroids have a disagreeable odor, not unlike that of decomposing urine. It therefore attracts insects that seek such odors, which find the flattened expansion of the spathe a convenient landing place. In the narrow portion of the spathe a ring of stiff hairs projects horizontally except the tips, which bend downward, making a perfect ring. A second ring occurs just above the pistils. These shrivel up

Fig. 49. (*Arum conceptifoloides*) with part of the flower just above the pistillate flowers a ring of stiff hairs; above the staminate flowers a small ring of hairs; at the base of the "flower" (*spathe*) a large number of small gnats (*Cerato pogon*).

before the upper. When the lower row is relaxed the insects remain for a time on the staminate flowers and get covered with pollen. The hairs of the upper ring also soon relaxes and the insects escape, and go to a second plant. Kerner von Marilaun records several thousand gnats belonging to the genus *Ceratopogon* in one "flower." In all sixteen species belonging to the genera *Chironomus*, *Limosina* and *Sciara*. In another aroid, *Dracunculus creticus*, flies like *Lucilia* and common beetles like *Aleochara fuscipes*, etc., occur. More than 250 common beetles have been found in a single flower of the Italian *Dracunculus vulgaris*.

Jack-in-the-Pulpit.

The large spathe is arched over the central column, the spadix; below the edges overlap. The spadix contains the flowers, mostly one kind, but also monoecious. It is

visited by small insects, the fungus gnats. The insects find their way in between spadix and spathe, the projection on the spadix prevents the insect from getting out above. Insects can find their way out where the edges of the spathe overlap, and Weed thinks that in older flowers the walls open wider, at any rate, in many cases gnats perish in the prison chamber.

— The Skunk Cabbage (*Symplocarpus foetidus*) has not only a disagreeable odor, but also color. It grows in swampy places and is visited by numerous flies that breed in these marshy places.

Colocasia odora. Some of the aroids are pollinated by snails. Delpino states that this species is pollinated in this way. Mueller says: "The spadix is covered in its whole length with normal and abortive stamens and pistils; only female flowers occur in the lower, wider part of the spathe, and they only are mature in the first period. From this chamber an attractive odor issues, and the snails are admitted by a narrow entrance. In the second stage this entrance closes, and the anthers dehisce. Snails which creep onto the flower in this stage seek vainly for the entrance, and dust themselves with pollen, which they afterwards carry to the stigmas of younger plants. Delpino supposes that the snails after affecting cross-fertilization, are poisoned by an irritant secretion within the chamber of the spathe, and are so prevented from devouring the flowers."

CHAPTER VI.

FLOWERS AND THEIR UNBIDDEN GUESTS.

Perforation of Flowers. It is a matter of very common observation that many of our flowers are perforated, and that insects obtain nectar without going to the proper sources. The beautiful colors and exquisite contrivances ~~are rendered inoperative~~ because of these perforations. The subject has been treated by Darwin¹ and others². Mr. Jack³ has also recently contributed a short note on this subject in which he cites a number of interesting cases. The chief perforators are bumble bees (*Bombus*), carpenter bees (*Xylocopa*) and wasps (*Vespa*.) Hive bees and birds have also been observed. Why should insects perforate flowers? Darwin believes that, as a general rule, flowers are only perforated when they grow in large quantities close together; for he found in a garden where *Stachys coccinea* and *Pentstemon argutus* were growing in large numbers, every flower was perforated, but at some distance from these was a small stock of *Stachys coccinea* the flowers of which were much scratched, showing that they had been visited by bees, although not a single flower was perforated. The same thing was noticed on a small stock of *Pentstemon*, growing in the same garden.

1 Cross and self-fertilization. Mueller, L. C., etc.

2 L. H. Pammel; Trans., St. Louis Academy of Science, vol. X, pp. 246-277, A bibliography is given in this paper.

3 Garden and Forest. Vol. V; p. 29.

The same fact holds true in *Trifolium pratense* when growing in fields, and *Phaseolus multiflorus* when grown in large and conspicuous clusters in gardens. It is a well-known fact that alpine flowers grow in much larger masses than plants of lower regions. Familiar examples of our flora are afforded by *Silene acaulis*, *Arenaria*, *Groelandica*, *Bryanthus taxifolius*, *Trifolium* sp., *Ledum*. etc. Mueller has shown of alpine and subalpine plants that more were visited in the Alps than in the lowlands and also that more species were perforated as is well shown by the list of flowers which *Bombus mastrucatus* visits.

Flowers grown in large masses are conspicuous, and therefore attract many insects ; and, as the perforated flowers usually contain considerable nectar, the number of insects visiting the flowers at any one time is very large, and, as Darwin has shown, some of the nectaries are sucked dry; now, in order to save time, for the flowers would have to be probed for their nectar, the insect makes perforations. To this rule there are exceptions, as has been shown in some of the cases cited, where an insect, unable to get a nectar in a normal way, takes to perforating flowers. Mueller and others have shown that there is a certain correlation between the length of the tongues of *Hymenoptera* and the flowers they perforate, as can be seen by consulting their tables on flowers and their visitors.

~~*~~ *How Flowers are Protected.* We have briefly called attention to a few of the agents which destroy flowers. It is equally interesting to study the contrivances which protect the flowers from unbidden guests. Darwin has well said in a prefatory letter to Dr. Wm. Ogle's translation of Kerner's admirable book on "flowers and their unbidden guests:" "The beauty and poetry of flowers will not be at all lessened

to the general observer by his being led through Kerner's investigation to notice various small and apparently quite unimportant details of structure, such as the presence of

FIG. 50.

Fig. 50. *Serratula lycopifolia* protected by the gummy involucre against a beetle (*Uxythyrea funesta*) and ants (*Formica*). (After Kerner von Marilaun).

differently directed hairs, viscid glands, etc., which prevent the access of certain insects and not of others."

Were it not for the contrivances in many flowers, very unwelcome guests would often enter the flower and utilize for themselves what legitimate visitors should have. Flowers are protected from unbidden guests in various ways.

1. Aquatic plants are protected by their isolation in water. Land plants have occasionally secured for themselves the same advantages in that certain leaves form cups around the stem. In others there is a leaf-cup at each joint, while in some there is a single basin formed of the rosette of leaves at the base. In these rain and dew not only collect, but are retained for a considerable time, as in *Dipsacus sylvestris*, *D. laciniatus* and *Silphium perfoliatum*.

2. By means of slippery leaves, which often have a curved surface, over which it is impossible for ants to climb, e. g., in *Gentiana firma*. In *Cyclamen* the reflexed lobes of the corolla are turned upwards, so that ants cannot crawl over them.

3. Plants, and especially parts near the corolla, are covered with hairs and spines; these often point downwards, as in flowers of *Salvia*, *Verbena*, *Linnea* and *Stachys*.

4. Some plants are especially distinguished by viscid and glutinous secretions. These occur on the stem in *Silene antirrhina*, on the involucre bracts of *Grindelia squarrosa*, on the calyx and stem of *Silene noctiflora* and on the young branches of *Robinia viscosa*, the secreting glands shriveling up when the flowers are pollinated.

5. Kerner believes that the milky juices of some plants, e. g. *Lactuca*, *Asclepias*, *Euphorbia*, *Apocynum*, *Chelidonium*, etc., serve to keep ants away. In an experiment he found that an ant, placed on a lettuce leaf, cut the epidermal tissue with its sharp claws so that the milky juice exuded, and, hardening, held the ant to the leaf.

FIG 51.

Fig. 51. Hairs acting against unbidden guests. 1, *Arctostaphylos uva-ursi*; 2, section of flower of *Centranthus ruber*, cut lengthwise; 3, cross-section of flower; 4, part of flower of tulip (*T. sylvestris*); 5, *Cobaea scandens*, showing hairs near base; 6, hairs on pistil of *Daphne blugayana*; 7, *Lonicera alpigena*; 8, *Vinca herbacea*; 9-10, stamen and pistil of the same. (After Kerner von Marilaun.)

CHAPTER VII.

CROSS AND SELF-FERTILIZATION IN PLANTS.

Cross Fertilization. Dr. Gray, in that charming little book, "How Plants Behave," says: "Close fertilization, that is, the fertilization of the seeds by pollen from the same flower is very close breeding indeed. It is the next thing to no fertilization at all in plants, that is to propagation by buds." From an elaborate series of experiments made by Darwin¹, supplemented by the work of others², there can no longer be any doubt that cross-fertilization is an advantage. Darwin has aptly said, "Nature abhors perpetual self-fertilization." [Since the appearance of Darwin's *Fertilization of Orchids* many contributions have been made to show the exquisite relations between flowers and insects.] Most observers agree that the structure of many flowers is for the purpose of securing cross-fertilization and to avoid self-fertilization, although there are those who are unwilling to see the utility in cross-fertilization. Thomas Meehan³, says. "It has never been clear to my mind that insects are any material aid to plants by the pollination which they often undoubtedly accomplish. There has been little to prove that in-an-in, or close breeding, is an injury;

1 Cross and self-fertilization in plants. See also different forms of flowers in the same species. Fertilization of orchids.

2 Hildebrand: *Die geschlechter vertheilung bei den pflanzen*, etc.

Mueller: *Fertilization of flowers*, English translation.

Lubbuck: *British wild flowers in relation to insects*, etc.

3 On the fertilization of *Cassia marylandica*, *Proc. Academy of Natural Sciences*. Philadelphia, Aug. 31, 1886, p. 314.

and it has been assumed that cross breeding among plants must be a benefit soely because arrangements for its accomplishments exist."

Long before Darwin's admirable researches appeared in print, some observers surmised that cross-fertilization is an advantage to the plant. Dean Herbert wrote in 1836⁴: "I am inclined to think that I have derived advantage from impregnating the flowers from which I wished to obtain seeds with pollen from another individual of the same variety, or at least from another flower rather than its own, and especially from an individual grown in a different soil or aspect."

Koelreuter, Sprengel and Knight had also observed many facts with reference to cross-fertilization, though they failed to see the full import of this question in its relation to plant life.

Dr. Gray⁵ says: "When Mr. Darwin announced the principle that cross-fertilization between the individuals of a species is the plan of Nature, and is practically so universal that it fairly sustains his inference that no hermaphrodite species continually self-fertilized would continue to exist, he made it clear to all who apprehend and receive the principle that a series of plants propagated by buds only must have a weaker hold of life than a series reproduced by seed."

Darwin⁶ was the first to place the subject on a scientific basis by means of a large number of experiments. He says, "That the injury from the close breeding of animals and from self-fertilization of plants does not necessarily depend on any tendency to disease or weakness of constitution, as

⁴ Henslow: *Origin of floral structures*.

⁵ *Darwiniana*, p 345.

⁶ Cross and self-fertilization, etc.

common to the related parents, and only indirectly on their relationship in so far as they are apt to resemble each other in all respects, including their sexual nature." Secondly, it will depend on a sexual element of the parents. The progenitors having been in some way exposed to different conditions, having been intercrossed. Thirdly, what Darwin calls spontaneous variation. Everyone is familiar with the practice of gardeners to obtain seed from different localities. The product is undoubtedly better, since the seeds were grown in soils of very different nature as well as climatic conditions. It would no doubt be better, as Darwin⁷ suggests, to sow the seeds raised in different localities in alternate rows. By crossing there would be a blending of the whole organization without in any way affecting the purity of the variety. Darwin made many experiments to determine the superiority of cross-fertilized plants over self-fertilized plants. I will give a few illustrations: A plant of cultivated morning glory (*Ipomœa purpurea*), grown from carefully selected seed, when ready to flower was protected with meshes one-tenth of an inch in diameter so that insects carrying pollen might be excluded. Ten flowers were fertilized with pollen from the same flower (self-fertilized). Ten other flowers on the same plant were crossed (cross-fertilized) with pollen from a distinct plant. The cross and self-fertilized plants were placed in damp sand and allowed to germinate. The two kinds were then placed under the same conditions. This was done during ten generations. At the end of the experiment the product of the cross was superior to the self-fertilized in every respect. In productiveness of capsules, the ratio of crossed to self-fertilized in the third generation was at 100-38. It is also noteworthy

7 Cross-fertilization, etc., p. 28, p. 58, etc.

that the seeds were as 100-94. In one of the latter generations of the fifteen first flowers pollinated from their own pollen, eight dropped off. While out of the fifteen of the self-pollinated of the cross-fertilized plants, only one dropped off. The impaired fertility of self-fertilized manifested itself in producing smaller anthers.

Darwin gives the following very apt illustration as to the height of self-fertilized plants⁸ :

“If all men in a country were on an average six feet high, and there were some families which had been long and closely interbred, these would be almost dwarfs, their average height during ten generations being only four feet eight and one-fourth inches.”

In the case of cabbage Darwin found that cross-fertilized plants were to the self-fertilized plants in weight as 100 to 37. When fresh stock was crossed the difference in weight in offspring was as 1,000 is to 22, showing a gain of over 350 per cent. Prof. Bailey also records marked superiority in crossed plants of cabbage. In regard to egg-plants Bailey says:

“In 1889 several hand crosses were made among egg-plants. Three fruits matured, and the seeds from them were grown in 1890. Some two hundred plants were grown, and they were characterized throughout the season by great sturdiness and vigor of growth. They grew more erect and taller than other plants near by grown from commercial seeds. They were the finest plants which I had ever seen. Prof. Munson, of the Maine Agricultural College, grew some of this crossed stock in 1891, and he told me that it was better than any commercial stock in his gardens.”

“In extended experiments in the crossing of pumpkins, squashes and gourds, carried on during several years, in-

crease in productiveness due to crossing has been marked in many instances. Marked increase in productiveness has been obtained from tomato crosses, even when no other results of crossing could be seen."

Darwin's experiments made with tobacco gave equally positive results. The crossed and self-fertilized plants were treated in different ways: Firstly, under very close competition; secondly, greatly crowded in large pots; thirdly, sown in poor and good ground so as not to be crowded. In each case the crossed plants were superior in every way. The crossed seed germinated easier, more rapid growth of the seedlings while young, and earlier flowering of mature plants. Ultimately they exceed in height also. The superiority of the crossed plants was plainly shown when they were weighed,—cross to self-fertilized was as 100-37. Hildebrand had similar results with a species of *Corydalis*. He cross-fertilized sixty-three flowers. Of these sixty-eight set fruit with 4.5 seeds per plant. He then self fertilized sixteen flowers of these; only three set fruit. He then self-fertilized twenty-seven flowers; none set fruit.

Behrens cites the following case: "Two tulips in separate pots were brought into the house shortly before the flowers opened. Gauze bags were tied over each of the flowers. When full grown the gauze was removed. One was self-fertilized and the other cross-fertilized. Both were again covered with gauze and left undisturbed. The result was that the cross-fertilized developed perfect fruit containing seeds capable of germinating. The close fertilized produced a stunted capsule with seeds incapable of germination."

Change of Seed. It may be well to refer here to the well-known belief that change of seed is advantageous. There can be no question that small changes will be benefi-

cial, but they may be also fraught with danger. The question of climate must always be taken into consideration. Bailey ⁸, who has given this question much attentions, says: "Even a slight change, as between farms or neighboring villages, sometimes produces marked results, such as more vigorous plants and often more fruitful ones. We must not suppose, however, that because a small change gives a good result, a violent or very pronounced change, gives a better one. There are many facts on record to show that great changes often profoundly influence plants, and when such influence results in lessened vigor or lessened productiveness we call it an injurious one. Now, this injurious influence may result even when all the conditions in the new place are favorable to the health and development of the plant; it is an influence which is wholly independent, so far as we can see, of any condition which interferes injuriously with the simple processes of growth. Seeds of native physalis or husk-tomato, were sent to me from Paraguay in 1889 by Thomas Morong, then traveling in that country. I grew it both in the house and out of doors, and for two generations was unable to make it set fruit, even though the flowers were hand-pollinated; yet the plants were healthy and grew vigorously. The third generation grown out of doors set fruit freely."

The husk-tomato experiment certainly shows that it is not advantageous to have very great changes. The plant must become accustomed to its new conditions before it will succeed.

Bolley, ^{8a} speaking of wheat seed, says: "Those who grew the samples associated with like varieties of home-grown seed have quite unanimously reported that there was no marked difference in growth and development."

⁸ Plant breeding.

^{8a} North Dakota Agricultural Experimental Station, Bull. No. 17, p 86.

"These tests and those recorded in Bulletin No. 13 are indicative of the same conclusion, viz. That our best varieties of wheat, as Blue Stem and Scotch Fife, are quite stable as to the characters which they maintain and transmit to the progeny under general methods of culture " A cross is good because new combinations enter. If these are desirable and strongly manifested, the plant is better fitted for the battle of life.

Bailey says: "For the purposes of this discussion it is enough to know that crossing within the variety and change of stock within ordinary bounds are beneficial, that the results in the two cases seem to flow from essentially the same causes, and that crossing and change of stock combined give much better results than either one alone, and this benefit is expressed more in increased yield and vigor than in novel and striking variations."

Darwin says on this point. "It is a common practice with horticulturists to obtain seeds from another place having a very different soil, so as to avoid raising plants for a long succession of generations under the same conditions; but with all the species which freely intercross by the aid of insects or the wind, it would be an incomparably better plan to obtain seeds of the required variety, which had been raised for some generations under as different conditions as possible, and sow them in alternate rows with seeds matured in the old garden. The two stocks would then intercross, with a thorough blending of their whole organizations, and with no loss of purity to the variety, and this would yield far more favorable results than a mere change of seed."

Impotency. John Scott¹⁰ observed that in a species of *Primula* (*Primula verticillata*), although the stamens and

¹⁰ See Hildebrand, *geschlechter vertheilung bei den pflanzen*, p. 68.

pistils are so arranged that self-pollination can take place readily, seed did not set unless pollen was brought from another plant.

Gaertner was unable to self-fertilize *Lobelia fulgens*, although fertile seeds were produced when the pollen of other species was used. The same state was found to exist in *Veibascum nigrum*, and according to Tinzmann in the potato (*Salanum tuberosum*).

Darwin,¹¹ Fritz Mueller and others, made observations to show that the pollen has no effect unless it comes from a different plant. It has been shown that the pollen from another flower of the same plant is scarcely more potent than pollen from the same flower. Now, the greater difference in the individual, the greater the potency. In some cases the potency is greater from a different variety. Fritz Mueller has made the interesting observation that in some plants when the pollen is placed on the stigma of the same flower, it has no more effect than dust. In other cases when the pollen of the same flower was placed on the stigma, it acted on it like poison. The flower faded and fell off. Flowers not so treated on the same branch remained fresh. Darwin has shown that in plants known as heterostyled the number of seed produced in illegitimate unions was small indeed and full fertility only resulted when the pollen from stamens was brought to styles of the same length.

It is well know that in Australia there was much difficulty in getting clover to seed until the introduction of the bumble bee. Experiments¹² have been made in this country as well as Europe to show that clover must be cross-pollin-

11 Different forms of flowers. Cross-fertilization, p. 219.

12 Darwin, cross-fertilization, p. 261, etc., etc.

Sirrinc: Bull, 13, Iowa Agri. Exp. Sta.

ated in order that it may set seed. The following experiment made by F. A. Sirrine on the college grounds, indicates clearly that self-fertilization does not occur in red clover. Two plants were covered with cheese cloth to prevent insects from getting in. In one plant nothing was done to see if self-pollination could take place. In the second case, which was a white spur of red clover, artificial pollination was effect with its own pollen. In neither case was seed obtained. "Whenever pollen from another variety was used seed set. Many grasses are cross-fertilized. Hackel¹³ says: "In some hermaphrodite flowers, cross-fertilization is so much the rule that they have lost the power of effectual self-fertilization, as in rye."

Cucurbits. Some years ago the writer made some experiments in crossing cucurbits. It was difficult to get seed when pollen from the same vine was used. Prof. Bailey had previously shown this to be true. He says: "The species are so exceedingly variable that all the hybrid individuals may be unlike, so that there can be no crossing between identical stock; and, if in-breeding is attempted, it may be found that the flowers will not in-breed. And the refusal to in-breed is all the more strange because the sexes are separated in different flowers upon the same plant. In other words, in my own experience, it is very difficult to get good seeds from squashes which are fertilized by a flower upon the same vine. The squashes may grow normally to full maturity, but be entirely hollow, or contain only empty seeds. In some instances the seeds may appear to be good, but may refuse to grow under the best conditions. Finally, a small number of flowers may give good seeds. I have

13 The true grasses. English translation, Scribner and Southworth, p. 18.

many times observed this refusal of squashes (*Cucurbita maxima* to in-breed."

Pears: Waite,^{13a} in his well known experiments, has shown that certain varieties of pear are self-impotent. His conclusions are as follows: "The results under those varying conditions have substantially agreed, in most cases being remarkably uniform. The fruits resulting from the different kinds of pollen showed interesting differences, which tend to corroborate the conclusions."

"It should also be noted that similar experiments were tried on the apple and the quince along with the pear work. The varieties of apples are more inclined to be sterile to their own pollen than the pears. With the former in the great majority of cases no fruit resulted from self-pollination "

"(1) Many of the common varieties of pears require cross-pollination, being partially or wholly incapable of setting fruit when limited to their own pollen."

"(2) Some varieties are capable of self-fertilization."

"(3) Cross-pollination is not accomplished by applying pollen from another tree of the same grafted variety, but is secured by using pollen from a tree of a distinct horticultural variety, i. e., which has grown from a distinct seed. Pollen from another tree of another variety is no better than from the same tree. This failure to fruit is due to the sterility of the pollen and not to mechanical causes."

"(4) The impotency of the pollen is not due to any deficiency of its own, but to the lack of affinity between the pollen and the ovules of the same variety."

"(5) The pollen of two varieties may be absolutely self-sterile and at the same time perfectly cross-fertile."

^{13a} The pollination of Pear Flowers. U. S. Dept. Agric., Div. of Veg. Pathology, Bulletin No. 5, pp. 81-82.

“(9) Pears produced by self-fertilization are very uniform in shape. They differ with crosses not only in size and shape, but also in some cases in time of maturity and in flavor.”

“(11) Self-fecunded pears are deficient in seeds, usually having only abortive seeds, while the crosses are well supplied with sound seeds.”

These same facts may be extended to many other plants, but space will not permit us to dwell on this at greater length.

Superiority of Crossed Plants. Behrens says: “Cross-fertilization produces the greatest number of seeds capable of germinating, while self-fertilization tends to produce few or no seeds capable of germinating. Self-fertilized ovaries, on the whole, produce *fewer* seeds than cross-fertilized. The seeds produced by self-fertilization are on the average smaller and lighter than those produced by cross-fertilization. The plants from self-fertilized are on the average smaller and weaker than those from cross-fertilized.”

Hermann Mueller¹⁴ comes to essentially the same conclusion, and adds, “that the product of self-fertilized can resist unfavorable conditions, such as sudden changes of temperature, much better. The superiority of crossed plants does not depend on the mere separation of the plants, but it brings together the properties of two individuals which have a slightly different constitution.” Gray¹⁵ says: “It is seen to be a part of the general ‘economy of nature,’ a phrase which has a real meaning. One good illustration of it is furnished by the pollen of flowers. The seeming waste in a

¹⁴ Die Wechselbeziehungen zwischen den blumen und den ihre kreuzung vermittelnden insekten.

¹⁵ Darwiniana, p. 375.

pine forest is enormous. It gives rise to the so-called 'showers of sulphur' which everyone has heard of." Myriads of the pollen grains are scattered by the winds to one which reaches the stigma to fertilize the ovule. In close fertilized flowers a small amount of pollen is produced. Now in the contrasted case, that of pine trees, the vast superabundance of pollen would be sheer waste if the intention was to fertilize the seeds of the same tree.

Wallace says.¹⁶ "The facts as to the cross-fertilization of flowers which have been briefly summarized, taken in connection with Darwin's experiments proving the increased vigor and fertility given by cross-fertilization, seem amply to justify his aphorism, 'Nature abhors self-fertilization,' and his more precise statement, 'No plant is perpetually self-fertilized.'"

Self-Pollination. In the flowers considered so far the intent appears to be to secure cross pollination, but there are many plants in which self-pollination is the rule. This is unknown in autogamy. Autogamy cannot, of course occur in any other but perfect flowers.

In *Adoxa moschatellina* the flowers are proterogynous. When the stigmas are receptive the anthers are short; they lengthen out and finally leave some of the pollen on the stigma. If cross-pollination has not occurred, there are still chances for self-pollination. In the early flowers of some species of *Geranium* the five stigmas are receptive. The anthers, of which there are ten, have not dehisced. In a day, or less in some cases, the anthers discharge their pollen on the stigmas. The flowers close at night, and the following morning the five stamens next to the corolla lengthen, straighten out and deposit their pollen on the stigmas.

¹⁶ Darwinism, see page 221.

Hermann Mueller, in giving a general retrospect on the subject of cross-pollination, says in regard to self-pollination; "Where cross fertilization that had once been insured becomes uncertain owing to the competition of other flowers, (e g. *Malva rotundifolia*, species of *Geranium*), or owing to the unfavorable locality (as *Lysimachia nemorum*) or unfavorable weather (as *Veronica beccabunga*), the mechanisms of the flowers have in many cases undergone a change such as to render self-fertilization again possible; in a few cases reversion to anemophily has taken place (*Artemisiaceae*, *Thalictrum*). As examples of the countless ways in which plants revert to self-fertilization in default of sufficient insect-visits, I may mention the following: In some dichogamic flowers the stigmas curl back upon the anthers or other parts which still retain some pollen (*Stellaria graminea*, *Malva rotundifolia*, species of *Geranium*, *Compositae*); the stigmas sometimes curl back till they come in the line of fall of the pollen (*Melampyrum pratense*) or even place themselves between the anthers (*Rhinanthus minor*); anthers which stand in a ring around the stigma, may, in default of sufficient insect-visits, converge above the stigma, applying their pollen to it (*Myosotis*, *Lithospermum*, *Cruciferae*); even mechanisms which effect cross-fertilization with astonishing precision in case of insect-visits are not unfrequently transformed so as to render self-fertilization inevitable when insect-visits are few (certain *Orchidaceae*, *Fumariaceae*, *Salvia*); or the production of cleistogamic, self-fertilized flowers may compensate for the loss of the power of self-fertilization in the ordinary flowers (*Viola*)."

Cleistogamous Flowers. The intent in these is certainly to have self-fertilization, and it is remarkable that the closed flowers are very productive of seed, more so than many

open flowers. Some of our violets and polygalas produce two kinds of flowers. The early ones are irregular and adapted to insect pollination. In the late flowers, which are closed, the pollen has been reduced to a minimum.

In a large number of plants self-fertilization is the rule. But many of these are occasionally self-fertilized so that the rule is not invalidated. But there are plants which have special arrangements for securing self-fertilization, as in some buttercups (*Ranunculus*) sandwort (*Spergula*), willow herb (*Epilobium*), but these may also be cross-fertilized occasionally. But there are cases in which there are no chances for cross-fertilization. Such are plants which produce cleistogamous or closed flowers. These, according to Darwin¹⁷, occur in twenty-four natural orders. But additions are constantly made, and Hemsley believes that they occur in nearly all the natural orders. In many plants which produce these closed flowers, irregular insect pollinated flowers are produced. These closed flowers produce a minimum of pollen, but an abundance of seed; much more so than do the flowers of the same plant pollinated by insects and therefore possibly cross-fertilized. Some of our violets

Viola palmata var. *cucullata*) often have these cleistogamous flowers, and although my observations are not crucial, I have seen the seeds in their pods much more abundant than in the irregular flowers produced early in the season. This is certainly the case in the dog violet (*Viola canina*). All of the plants that produce cleistogamous flowers also have those of other kinds; not always in the same locality, as in a small rush (*Juncus bufonius*). In some places this plant produces closed only, while in other parts perfect flowers are produced.

17 Different forms of flowers.

Autogamy and Alpine Plants. Loew, in his "Blütenbiologische Floristik," has collected statistics of the observations made upon flowers with reference to insect visitors and autogamy, from which it appears that self-fertilized plants are more numerous among alpine species than among those of a lower level. Observations are not at hand to indicate whether the same state of affairs exist in this country, but I am inclined to doubt that this is true for Rocky Mountain species. Kerner accounts for autogamous flowers in these regions because of the shortness of the season and the broken condition of the weather. While the climate above timber line in the Rocky Mountains is rigorous and at times unfavorable, the mornings are usually bright and sunny. A few hours spent in collecting the insect fauna on such alpine plants as *Mertensia*, *Primula*, *Omphalodes*, *Silene*, *Actinella*, *Trifolium* and *Astragalus* leaves some doubt in my mind in regard to autogamy.

Autogamy in Grasses. Hackel says in regard to barley: "Cross-fertilization is much more rare and difficult in barley, and in certain races like the six-ranked, the short-spiked, two-ranked and the peacock barley. The flowers, especially in our climate, never open and consequently cross-fertilization is made impossible."

Two of our native grasses (*Leersia oryzoides* and *Amphicarpum Purshii*) produce cleistogamous as well as the ordinary flowers. The closed flowers are abundantly fertile, while the others are not. Meehan says:¹⁸ "All plants that are arranged for self-pollination are abundantly fertile and have a great advantage of numbers in the struggle for life.

¹⁸ Proceedings Academy of Natural Sciences, Aug. 26, 1890. See p. 271. Also May 26, 1890, Proceedings American Association for the Advancement of Science, Detroit meeting, etc.

While those that have to depend on external agencies are usually less productive, and even though the progeny may be found to have greater vegetative vigor, or some other element of strength.

Mr. Henslow says: "Thus orders of plants with easy access to the honey are some of the most abundant, as *Ranunculaceae*, *Compositae* and *Umbelliferae*, as well as are those dependent upon the wind which never fails, such as willows, *Cyperaceae*, and grasses. On the other hand all regularly self-fertilizing plants are abundant, and, together with certain wind-fertilizing plants, are cosmopolitan."

Cause for Cleistogamy. Kerner makes the following suggestion in regard to the conditions affecting cleistogamous flowers: "No open, aerial flowers were produced by *Viola sepincola* so long as it grew in the cool shade of a dense wood, but when transferred to open ground, accessible to sunlight. such flowers were developed. One can hardly err in ascribing to the sun's rays a very important influence in stimulating plants to the inception of flowering shoots, especially such as bear blossoms possessing bright-colored petals. Indirectly, however, this advantage accrues to the plants in question, that, living as they do in the deep shade, where no bees would, in any case, visit them if they had open flowers, they can confine their constructive energy to the inception and development of cleistogamous flowers and save themselves the trouble of producing open flowers adapted to cross-pollination (but useless in the place in question). If the spot where the violet grows becomes exposed to the sunlight through the trees shading it being blown down or felled, bumble and hive bees make their appearance in search of honey, and buzzing from flower to

flower, crosses one with another." Climate is no doubt an important factor.

Now, everyone knows how vigorous are plants like knot-weed, horse-weed, buttercups, thistle, plantains, etc. They are world wide and it is equally true that they are self-fertilized. Wallace says: "That self-fertilization has some great advantages is shown by the fact that it is usually the species which have the smallest and least conspicuous flowers which have spread widely, while the large and showy flowered species of the same genera or families, which require insects to fertilize them have a much more limited distribution."

It must be admitted that inter-crossing is not necessarily good, but also that close inter-breeding is not necessarily bad. Says Wallace: "The rabbits on the Island of Porto Santo have originated from a single female. They have lived there for 470 years and are still vigorous." But close inter-breeding does produce bad results, especially if care in selection is not used. The inter-breeding is not injurious if there is a change of conditions and proper selection.

Wallace concludes: "From a consideration of these varied facts we conclude that an occasional disturbance of the organic equilibrium is what is essential to keep up the vigor and fertility of any organism, and that this disturbance may be equally well produced, either by a cross between individuals of somewhat different constitutions, or by occasional slight changes in the condition of life." In plants of wide dispersion there is a constant change of conditions; these can exist for a long time without inter-crossing, but in plants not so widely distributed a cross is needed to keep up the fertility. Why the production of an enormous quantity of pollen in case of the pine and other wind

pollinated flowers if self-fertilization is more advantageous? Pollen is rich in nitrogen, and this is a costly element. Why the exquisite adaptations in orchids and other flowers if self-fertilization is preferable? We are justified in concluding that cross fertilization is advantageous.

CHAPTER VIII.

THE EFFECTS OF CROSS-FERTILIZATION IN PLANTS.

There has been much discussion, both popular and scientific, on the question of the effects of cross-fertilization in plants. It is conceded by all authorities that there is an effect, the point at issue is mainly whether it is immediate or manifests itself later. Most authorities now agree that it is immediate in some cases at least. It is well known that in some cases pollen has an immediate influence on the fruit or seed. This has long been known to be the case in corn. As long ago as 1858¹ it was observed that when differently colored varieties grew near each other they affected each other's seed. Later experiments were tried by Dr. Savi and Hildebrand. Both have come to the same conclusion. P. Dudley² writes as follows: "Indian corn is of several colors, as blue, white, red and yellow. If these sorts are planted by themselves, so that no other be near them they will produce their own color; but if you plant the blue corn in one row of hills as we term them, and the white or yellow in the next row, they will mix and interchange color." Dr. Sturtevant³ says: "Corn, the maize plant, shows in its kernels the influence of cross-fertilization of the same year. Some varieties seem to possess the power of resisting either

1 Darwin: *Animals and plants under domestication*, Vol. I. p. 430.

2 *Philosophical Transactions Abridgement*, Vol. VI, Pt. II, p. 204-205.
Kellerman and Swingle, *Second Annual Rep. Kansas Agrl. Exp. Station*, 1889, p. 345

3 *Second Annual Rep. New York Agrl. Exp. Station* p. 37-56,

1 Leaves of New Prolific Marrow, (*Cucurbita maxima*).

2 *Cucurbita pepo* to the right vegetable marrow, to the left the product of a cross between vegetable marrow and long warted.

3 *C. maxima*, from seed grown in with *c. pepo* mixed with prolific marrow.

4 Variations of perfect gem (*C. pepo*), the type shown to the left; in color all were perfect gem, but in form variable, showing effect of pumpkin, long warded, &c.

5. Common pumpkin (*C. pepo*) on nest-egg gourd, *C. pepo*; all photographed by F. A. Sistrine.

cross-fertilization or the changes induced thereby. Crozier ⁴ writes (Cross between Stowell's Evergreen and Yellow Hathaway): "These observations show that foreign pollen effects the appearance of the crossed kernels the first season, but also that an unusual appearance may be due to a cross of the previous year. Prof. Beal⁵ says: "During the year past I planted near each other three hills of the following kinds of corn, well mixed together, viz.: Waukashum, White Flint, Black Pop Corn, Early Minnesota Sweet, King Phillip and Black Sugar. Every ear showed a mixture produced by pollen from one or more of the varieties except those of the King Phillip variety."

But flint corn⁶ did not show the effect of pollen from dent corn in the first year. Kellerman and Swingle⁷ who crossed a large number of varieties have come to the same conclusion that other observers have; namely, that the so-called varieties of maize cross more or less freely, and the effects may or may not be visible the first year. As a result of some work done on the college grounds Professors Crozier and Rolfs⁸ write concerning the immediate influence of cross-fertilization upon the fruit: "In all cases some, and in some cases all of the ears changed in appearance in the direction of the variety furnishing the pollen." A practical gardener, Mr. F. S. White,⁹ writes as follows: "The past season I had sixteen varieties of white sweet corn, and also a small lot of Black Mexican. When I came to save my seed corn I found grains of this black corn stuck in every variety."

4 Proceedings Soc. Prom. Agrl. Science 1887, p. 1.

5 Report State Board of Agriculture, Michigan, 1879, p. 198.

6 Beal: Report State Board of Agriculture, Michigan, 1878, p. 450.

7 Second Annual Report Kas. Agrl. Exp. Station, 1889, p. 288. See also First Annual Report, p. 316.

8 Agricultural Science, Vol. IV. p. 23.

9 Iowa State Register, December 11, 1891.

In 1896 a neighbor planted some popcorn in close proximity to sweet corn. In every case there was an immediate effect. Cases of this kind are numerous.

I have given enough evidence to show the immediate influence of pollen on corn. It is only necessary to add that in some cases it would seem that the varieties of corn are not sufficiently fixed, and that a change from the type may be due to a previous cross.

The opinions in regard to other plants are very diverse. Crozier¹⁰ says. "The writer is disposed to think that the evidence is still insufficient to show that there is an observable effect of cross upon the ovary the first year except in Indian corn."

Darwin observes that when white and blue varieties of the pea are planted near each other, they mutually cross, and in the autumn, blue and white peas were found in the same pod. There has been much discussion concerning the immediate effects of the pollen of certain varieties of the orange. Budd assures me he has made personal observations in California, and thinks there can be no question as to its immediate effects. Darwin cites a case in which Gallesio¹¹ fertilized the flowers of an orange with pollen from the lemon; and one fruit thus produced bore a longitudinal stripe of peel having the color and flavor of a lemon.

California orange-growers are convinced that the naval orange shows itself where this pollen is used. In several hybrid plums and grapes that I have seen, no immediate effects was visible, although there is said to be an immediate effect in some pears, and Waite found this notably true in his experiments.

10 Department of Agriculture Report, 1887, p. 213.

11 Darwin: animals and plants, etc., p. 430.

In regard to the apple there is some difference of opinion. There are many who believe the action is immediate. Crozier and Rolfs in experiments made a few years ago on the college grounds found no difference when the Oldenburg apple was crossed, although the pollen was obtained from ten different varieties, using it as a female plant. The fruits were all alike and resembled uncrossed specimens of the Oldenburg. The Iowa State Horticultural Society has at its trial stations done much crossing and hybridizing. Numerous varieties were crossed on the Soulard and other forms of the wild crab (*Pyrus coronarius*). Collman, Fluke and Watrous all inform me that they could see no immediate effect of the pollen on the wild crab. It was in all essentials a wild crab. Darwin, however, gives evidences to show that the effect may be immediate in some cases. In another case a smooth apple affected a rough coated kind. The remarkable St. Vallery apple, in which the stamens are abortive and do not produce pollen, is of interest in this connection. When artificially pollinated the fruit differs in size, flavor and color, but resembling in character the perfect kinds with which they have been fertilized. This case may not be so strong as started by Darwin. Crozier, who looked up the original French reference, think there is some doubt in regard to it. I have several times had my attention called to apples which plainly showed two varieties; in one case an apple was half Baldwin, the other half was a greening. Some years ago I saw some apples, one-half of which were gros pomier, the other half was unknown to me. It was thought that these showed an immediate effect, but I was unable to get a further history of the case.

It is a very common belief that there is an immediate effect in the crossing of cucurbits. Such is, however, not

the case. Prof. Bailey, who has made more than a thousand careful hand pollinations and has obtained more than a thousand types of pumpkins and squashes, has never seen any immediate influence, except such as was due to imperfect development, caused by insufficient or impotent pollen.

Several years ago, in conjunction with Mr F. C. Stewart, some experiments were made in crossing cucurbits. Many careful hand pollinations were made, but in not a single case was any immediate effect observed. When this seed was planted the following year hundreds of new forms made their appearance. We are justified in concluding that there is no immediate effect.

Charles Darwin: *Animals and plants under domestication*. Vol I, p. 430.

P. Dudley: *Philosophical Transactions Abridgement*, Vol. VI, Pt. II., p. 204-205.

Kellerman and Swingle, *Second Annual Rep. Kansas Exp. Sta.*, 1889, p. 346.

Lewis Sturtevant: *Second Annual Rep. New York Agrl. Exp. Sta.*, p. 37-56.

A. A. Crozier: *Proceedings Soc. Prom. Agrl. Science* 1887, p. 1.

W. J. Reel: *Report State Board of Agriculture, Michigan*, 1879, p. 198.

Beal: *Report State Board of Agriculture, Michigan*, 1878, p. 450.

Kellerman and Swingle: *Second Annual Report Kas. Agrl. Exp. Station*, 1889, p. 288. See also *First Annual Report*, p. 316.

Crozier and Rolfs: *Agricultural Science*, Vol. IV, p. 23.

F. S. White: *Iowa State Register*, December 11, 1891.

A. A. Crozier: *Department of Agriculture Report*, 1887, p. 312.

Focke: *Pflanzenmischlinge*, p. 475.

P. H. Pammel: *On the Crossing of Cucurbits*, bulletin No. 19, Iowa Agricultural Experiment Station, pp. 595-600, November, 1892.

The Crossing of Cucurbits, proceedings of the sixth annual convention of the Association of Agricultural Colleges and Experiment Stations, New Orleans meeting, November 15-19, 1893, pp. 94-97.

On the Crossing of Cucurbits, transactions Iowa Horticultural Society, 1892, volume xxvii, pp. 327-332.

Brandza, *Rev. Gen. de Bot.* 1890, pp. 301-305. *Bot. Centralblatt*, XLVI, p. 124 and p. 40. Hildebrand, *Bot. Centralblatt* Vol. XL, p. 46.

Macfarland: *Botanical Gazette* Vol. XVI, p. 255. *A Comparison of the Minute Structure of Plant Hybrids with that of our Parents and its bearings on Biological Problems*. Transactions of the Roy. Soc. Edinburgh XXXVII, pp. 203-238. *Bot. Centralblatt* LIII, p. 379.

L. P. Pammel: *Cross Breeding of Plants and Hereditary*, *Rural Life*, Oct. 19, 1893, p. 12.

Vilmarrin: *Pedigree or Grade Races in Horticulture*, *Gardner's Chronicle* Vol. XIV, 3d series p. 301, p. 332. See p. 332.

CHAPTER IX.

HYBRIDS.

Camerarius, in 1694, thought, on certain grounds, that hybrids could occur, and Gmelin found a new *Delphinium* in his garden which he concluded was a hybrid. Linnaeus appears to have been successful in the production of a hybrid between *Tragopogon pratensis* and *T. porrifolius*; this flowered in 1759, though as early as 1719 Thomas Fairchild produced a hybrid of *Dianthus Caryophyllus* and *D. barbatus*.

As early as 1791 Koelreuter produced a large number of hybrids. These early experiments in hybridization gave undoubted proof to those who doubted it, of the sexuality of plants. Koelreuter produced his first hybrid between *Nicotiana rustica* and *N. paniculata*. Thomas Andrew Knight, during the latter part of the Eighteenth Century, did a great deal of work in hybridization.

Of the later workers, from 1826 to 1880, mention should be made of Gaertner, Herbert, Naudin, Gadron, Focke and a host of modern workers.

The term cross is used to designate the offspring from the union of two different plants of the same species or variety, the union of the variety being more violent than that of the same species. The hybrid is the result of the union between two species, as blackberry and raspberry. It is difficult in some cases to say what constitutes a species, as botanists do not always agree as to its limits. In some few cases hybrids have been produced between two distinct

genera, as in the case of wheat and rye hybrids, or those of *Brassica* and *Raphanus*, also in *Lychnis* and *Silene*; *Aegilops* and *Triticum*. They are not uncommon in certain orders, as in the pink, cactus and orchid families.

In a state of nature hybrids are not common. A full list up to 1881, is given by Focke. They are most numerous in willows, oaks and verbenas. Prof. Bailey who has given *Carex* much attention, states that out of one hundred and eighty species in the Northeastern States, only eleven hybrids are recorded. When we come to cultivate plants, Prof. Bailey says: "Hybrids have been produced between the raspberry and blackberry by two or three persons, but they possess no promise of economic results. Among the list of garden vegetables (plants which are propagated by seeds) I do not know of a single important hybrid."

"It is true that there are many grape hybrids like the Agawam, Lindley, Wilder and Brilliant, and of pears like the Kieffer. In ornamental plants hybrids are numerous and in many of these they are carefully cultivated and nursed. If these plants are left to shift for themselves, they soon lose their charm."

Focke concluded that the parental characters may be variously intermingled; (1) a mean between both parents is maintained in all parts of the plant, (2) the characteristics of the father or mother predominate, (3) certain parts of the hybrid exhibit the maternal and others the paternal characters.

Weismann, in speaking of the control of parental characters, says: "In any inquiry with regard to the factors which control the struggle of the parental characters, it must, above all, be borne in mind that *the cells are always the determining agents*. The determinants of the father and

mother come together in the cell, and in the cell only; and all characters, whether relating to a large part of the organism, or merely to a single cell, can only be determined by processes taking place within the substance of one or of many cells "

Kerner says: "Some of their attributes and external characters are derived from the paternal, some from the maternal stock. If the relative admixture of the two stocks were to be determined in the case of the hybrid by summing up the characteristics transmitted from each source, the share of each parent would, in many cases be found to be half. In such a case it is usual to say that the hybrid is a mean between its parents. Examples are afforded by *Geum hybridum*, which originates from crossing *Geum montanum* and *G. rivale*."

Hybrids are changed with reference to the production of seed, so much so that hybrids seldom if ever produce seed, and therefore do not propagate sexually. They show a marked change with reference to variability. In closely related species they flower earlier and longer with usually a luxuriant growth.

Focke states that he is of the opinion that genera with zygomorphic flowers, belonging to orders with actinomorphic flowers, show especial predilection for hybridization. *Pelargonium* of *Geraniaceae* and *Nicotiana* of *Solanaceae*. It appears to be difficult to hybridize plants growing in different situations.

"As a general thing, when species are closely related hybrids are more easily produced, as in many *Solanaceae*, *Caryophyllaceae*, *Iridaceae* *Salicaceae*. In other orders it is difficult to obtain hybrids, as in *Coniferae* and *Leguminosae*. Species of *Vitis*, *Salix* and *Dianthus* hybridize readily, but

Silene with difficulty; *Nicotiana*, *Verbascum* and *Geum* easily, but *Solanum*, *Linaria* and *Potentilla* with difficulty. Sometimes hybridization will not occur in closely related species, as the apple (*Pyrus malus*) and pear (*P. communis*).

Kroelreuter observed in his hybrids that in part they partook more of the mother than of the father, or the reverse. In some cases where one parent had yellow flowers and the other red, the hybrid had variegated flowers. When a hybrid was produced between an early-flowering and a late-flowering plant, the hybrid was between the two in time of flowering.

Hybrids of species of closer relationship, or the crosses are usually strong and productive. Such plants are characterized by their greater size, rapid growth, early maturation of the flowers, longer life, greater productiveness and unusual size of the separate organs. In hybrids produced from *Rhododendron arboreum* and *Catawbiense* the flowers mature earlier. In some species of *Rhododendron* and many other plants hybrids are sterile. Hybrid seedlings of *Nymphaea alba* are difficult to grow.

Hybrids of *Salix viminalis* and *S. purpurea* are said to be much more sensitive to frost than the species. On the other hand crosses of *Nicotiana suaveolens* and *N. tabacum-lattissimum* resist frost better than the species.

Focke adds, "That hybrids of different species contain less pollen in their anthers than those of the mother plant, and the fruit contains a smaller number of seeds. Frequently they contain neither pollen nor seed." It is also a well-established fact that the closer the relationship between species the easier it will be to obtain fertile hybrids.

Sachs says: "The characteristics of the parent-forms are as a rule so transmitted to the hybrid that the influence

of both is manifested in all its characters, producing a fusion of the different peculiarities. This is more evident in the species than in the variety hybrids; in the latter some of non-essential characters of the parent sometimes present themselves in the offspring uncombined side by side; *e. g.*, various kinds of streaks and blotches instead of a mixing of the colors of the flowers. Thus a hybrid which Sagaret obtained from *Cucumis Chate* (female) with *C. Melo Cantalupus* (which had a reticulated flesh) had a yellow flesh, a reticulated marking of the rind and moderately prominent ribs like the male parent, but white seeds and an acid flavor like the female parent. Another hybrid from the same species had, on the contrary, the sweet flavor and yellow flesh of the male, with the white seeds and smooth rind of the female parent.

As a rule, hybrids may be produced reciprocally, but sometimes this does not occur. Thus Koelreuter found that when the pollen of *Mirabilis longiflora* was applied to *M. Jalapa*, a hybrid was produced, but the reverse experiment failed.

Rose Hybrids. An extraordinary number of rose hybrids have been produced. It is said that on the average sixty new rose hybrids come on the market every year. The statement has been made that more than 6,400 roses have been produced up to the present time by crossing and hybridization.

Quite a large number of hybrids have been produced at the Iowa Agricultural College between *Rosa rugosa*, *Rosa Arkansana* and cultivated roses.

Rosa rugosa and *General Jacqueminot*. They present some remarkable variations. In color of flower, leaf and seed the hybrids indicate weaker germinating capacity.

J. L. Budd and N. E. Hansen state that "The tallest hybrids showed the most marked modification in foliage. One hundred and thirty-two of the plants showed marked variations, many of them showing no rugosity of leaf, while others are intermediate in foliage. Those following most nearly crenate, while those of the hybrids showing no rugosity of leaf are serrate. The rugosa leaflets vary in number from five to nine, the usual number being seven, and a few of the points of growth only five.- In some of the hybrids the usual number is five, with an occasional leaf bearing seven, and the leaflets average larger in size, Several of the hybrids have very small leaflets, and are dwarf in habit."

The *Rosa rugosa* evidently exerted a prepotent influence and this has also been observed in other hybrid roses, where the *rugosa* ovules were fertilized with other pollen. The rugosity of the leaf is certainly marked in many cases.

Apple. We have on the college grounds a hybrid between the Oldenburg apple (*P. Malus*) and *P. Torringo*, in which the character of leaf and flower are somewhat intermediate. The flowers of the hybrid are very much smaller than those of the Oldenburg, but larger than those of Torringo. The leaves are larger than those of Torringo, but not so large as those of the Oldenburg. The fruit is somewhat larger than that of *P. Torringo* with the peculiar blush of the Oldenburg.

Miss Sirrine, who made a microscopical examination of the hybrid and the parents, found that the offspring had many of the internal character of the parents, which substantiates the work of Macfarlane and others.

Another interesting hybrid is the Soulard crab. This was at first supposed to be a good species, but it has the

undoubted characters of *P. Malus*. However, it shows that *P. coronaria* had a strongly prepotent influence upon it.

Curbits. Do squashes and pumpkins mix with watermelons? Mr. F. S. White says: "This is a question that has been a puzzle to many, because we never see a pumpkin seed in a melon, nor is there any change in the melons, or apparant mixture in the seed. Yet I am sure that melons grown near pumpkins will get so mixed with the pumpkins as to be unfit for use." Now this is a general belief among gardeners, and my friend Mr. White states the case from his observations, but I desire to correct an error due to a misunderstanding of the limits of species. What is commonly called a squash is a pumpkin, *Cucurbita Pepo*, and not squash, *C. maxima*. Equally general is the belief that cucumbers spoil muskmelons. Prof. Bailey has shown that it is extremely doubtful. Ninety-seven muskmelons of many varieties were pollinated with cucumber pollen of many kinds. No fruit set. Twenty-five cucumber flowers were pollinated with muskmelon pollen; only one fruit developed, but that was seedless. In our own experiments in no case was there any evidence of "mixing" between the squash and pumpkins and melon and pumpkins. The off flavor in melons is due to reversion.

Lilies. Parkman has recorded some interesting observations on the hybrids between two Japanese lilies, *L. speciosum* and *L. auratum*. The pollen of *L. auratum* was applied to the stigma of *L. speciosum* and the result was that some good seed was produced. It appears that in the fifty young plants produced the stems were mottled like *L. auratum*, showing the influence of the male parent. The flowers of the first were like those of *L. speciosum* but having the fragrance of *L. auratum*. Now, of the other hybrids, not a single one

was distinguishable from pure *L. speciosum*. As stated before, the markings of the stem were those of *L. auratum*, consequently there was no doubt of their hybrid origin.

It is interesting to note here the variability or the difference in the influence of the male parent. This same fact has been observed in many other hybrids where there are many seeds in a vessel, and has also been observed in plants like the thistle with many achenes in one head.

Sachs says: "When two species, A and B hybridize, and the one species A exercises a greater influence on the form and properties of the hybrid than the other species B, the hybrid or its descendants, if fertilized by A, will revert more quickly to the parent form A than it will to the parent form B if fertilized by it. Thus Gaertner states that the hybrid of *Dianthus Chinensis* and *D. Caryophyllus* reverts to the latter form after three or four generations if repeatedly fertilized by it, while it requires fertilization for five or six generations by *D. Chinensis* in order to revert to that form."

Ternary Hybrids. A ternary hybrid is one which directly is the offspring of three different species in this way, the hybrid offspring of two species is united with the pollen of a third species, as, for instance, the hybrids of *Linaria genistifolia* and *L. purpurea* is fertilized with the pollen of *L. striata*. The result is a ternary hybrid. Some of these hybrids are not uncommon, for instance it is said that Wichura produced a compound hybrid in which six different willows entered.

Prepotency. It has been shown by numerous observers that when two races are crossed or the product a hybrid between two distinct species the result is a blending of the characters of both. It has even been asserted by some in-

vestigators that this character is shown in the make up of the cell-tissues. Macfarlane in an interesting address before the American Association of the Advancement of Science in Washington has shown that some hybrids are exactly intermediate in histological character between parents, and that normally there is an equal blending of both parents. We have had under observation in interesting hybrid between DeSoto plum (*Prunus Americana*) and an Oregon plum (*Prunus domestica*?) In habit of tree and foliage the hybrids assume the character of *Prunus americana* our wild plum. This variety is strongly prepotent in transmitting tendency to take a disease (*Cladosporium carpophyllum*) which does not occur on our cultivated European plum (*Prunus domestica*). But this is by no means the invariable rule. Darwin says. "It would appear that in certain families some ancestor, and after him others in the same family have had great power in transmitting their likeness through the male line." Henry L. LeVilmora says:

"In framing the character of the progeny the action of each parent is often very unequal, according to the power of each in transmitting its characters. The one that is better endowed in that respect stamps its features more firmly on the cross-bred plant. Discussions have arisen on the influence of the male and of the female progenitor on a cross. I believe that the strongest organism of the two, the one rather which is best endowed with the power to transmit its characters will predominate in the progeny, whether it comes from the male or female parent."

Graft Hybrids. There has been considerable discussion on the question of graft hybrids. Gardeners and horticulturists have maintained that hybrids have often been produced by budding and grafting. One of these has become

well known from the researches of Charles Darwin, a common laburnum. We will let Darwin describe the case: "To behold mingled on the same tree tufts of dingy-red, bright yellow, and purple flowers, borne on branches having widely different leaves and manner of growth, is a surprising sight. The same raceme sometimes bears two kinds of flowers, and I have seen a single flower exactly divided into halves, one side being bright yellow and the other purple, so that one-half of the standard petal was yellow and of larger size, and and the other half purple and smaller. In another flower the whole corolla was bright yellow but exactly half of the calyx was purple. In another one of the dingy-red wing petals had a narrow, bright yellow stripe on it; and lastly, in another flower. one of the stamens, which had become slightly foliaceous, was half yellow and half purple; so that the tendency to segregation of character of reversion affects even single parts and organs. The most remarkable fact about this tree is that in its intermediate state, even when growing near both parent species, it is quite sterile; but when the flowers became pure yellow or purple they yield seed. I believe that the pods from the yellow flowers yield a full complement of seed; they certainly yield a larger number."

"On the other hand, we have a clear and distinct account given to Poiteau by M. Adam, who raised the plant, showing that *C. Adami* is not an ordinary hybrid; but is what may be called a grafted hybrid, that is, one produced from the united cellular tissue of two distinct species. M. Adam inserted in the usual manner a shield of the bark of *C. purpureus* into a stock of *C. laburnum*; and the bud lay dormant, as often happens, for a year; the shield then produced many buds and shoots, one of which grew more upright and vigorous with larger leaves than the shoots of *C. purpureus* and was consequently propagated."

“If we admit as true M. Adam’s account, we must admit the extraordinary fact that two distinct species can unite by their cellular tissue, and subsequently produce a plant bearing leaves and sterile flowers intermediate in character between the scion and the stock, and producing buds liable to reversion; in short, resembling in every important respect a hybrid formed in the ordinary way by seminal production.”

It may be interesting to mention here that Macfarlane has examined the anatomical details of the tissue of this alleged grafted hybrid and it shows a remarkable mingling of the two parent forms.

In addition to this there is the famous Bizzario orange, which is said to offer a strictly parallel case. It is said that the tree produces at the same time leaves, flowers and fruit identical with the bitter orange and the citron of Florence; also fruit with the two kinds blended together both externally and internally.

It is said when the variegated Jessamine is budded with the common kind, the stock sometimes produces buds bearing variegated leaves.

We may mention here the instance of the Jerusalem artichoke (*Helianthus tuberosus*) which was grafted on the common sunflower (*H. annuus*). It was stated that the sunflower had acquired from the artichoke the habit of producing tubers. Voechting has lately repeated this experiment, but failed to get results anything like those recorded above for the sunflower.

On the whole, I think it may be questioned whether there is such a thing as a genuine grafted hybrid; it is best to suspend judgment until these are produced by actual experiment. Most of these statements rest upon the stories related by gardeners, and these are not always trustworthy.

Water Hemlock (*Cicuta maculata* L.) with flowers in masses.