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ON THE PHENOMENA OF SEX TRANSITION
IN *ARISAEMA JAPONICA* BL.

By

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(With one Plate and nine Text-figures)

Introduction.

Araceae comprises the hermaphrodite *Monsteroideae* and *Calloideae*, the hermaphrodite or rarely monoecious *Prothoideae* and *Pistioideae*, and the monoecious or rarely dioecious *Aroideae* (A. Engler, 1920, S. 63-66). Among the last subfamily of *Araceae*, *Arisaema* occupies a peculiar position owing to its dioecious nature.

Four species of *Arisaema* are known to grow wild in Hokkaido. Among them, *Arisaema japonica* has the widest distribution in the forests of Hokkaido. During my short stay at Tomakomai in the spring of 1916, I found it growing in abundance in the Experimental Forest of the Hokkaido Imperial University, where I was fortunately able to collect 231 corms with which I have been conducting experiments concerning their sexual nature since 1917.

As a result of my experiments with *Arisaema japonica*, I was able to establish the fact that the species undergoes some conspicuous sex transformations in a very regular way, which I have designated as "The Phenomenon of Sex Transition". By "Sex Transition" I mean that the transformation of sex does not occur at random under ordinary conditions, but sex is transformed in a definite manner from year to year. The process of sex transition in *Arisaema japonica* commences in its asexual state, then follows the male state, and lastly comes the female state, in which the plant continues to thrive for years.

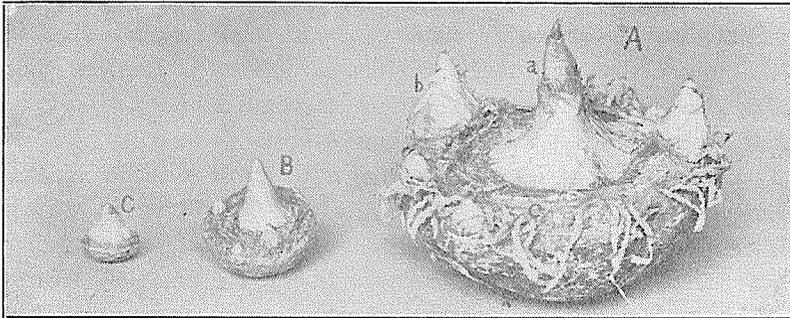
Sometimes, the order in which this sex transition takes place is reversed, and to this phenomenon I have given the name, "The Retro-Transition of Sex". It is an interesting fact that this Retro-Transition of Sex is limited to certain conditions, so that if the condition which brings about such an abnormal sex transformation is removed the plant

readily recovers the normal course of sex transition. The writer's aim was to investigate this problem in detail so as to elucidate the nature of sex transition together with the moment of sex determination.

I. On the Morphological and Ecological Aspects of *Arisaema japonica*.

1. Morphological Aspects.

The corm. The form of the corm is more or less hemispherical, bearing an obconical bud in the center and several cormlets on its upper shoulder. [Text-fig. 1, (A) a and b].



Text-fig. 1. Female, male, and asexual corms in the resting stage. (A) A female corm; a, apical bud; b, cormlet; c, root zone. (B) A male corm. (C) An asexual corm.

The apical bud is enveloped on the outside by several membranaceous bracts and on the inside by a few thick, soft and porous bracts. Every bract has an axilar bud which grows into a cormlet in the next vegetative period, but never develops into a vegetative shoot. The roots are filiform, branching, running almost horizontally, and forming a narrow (ca. 0.5 cm) root zone girdling the basal part of the apical bud [Text-fig. 1, (A) c].

Apical bud. The differentiation of an apical bud for the next year's growth is not finished until autumn. This young apical bud consists of two well differentiated foliage leaves and a young scape provided with a well differentiated terminal spadix upon a short rachis (ca. 3 cm) in the axil of the upper leaf (Plate IV, Figs. 4, 5, 6, 7, 19, and 20). On the whole surface of the young spadix are regularly arranged a great number of very young unisexual flowers, so that we can tell the sex of the spadix at a glance.

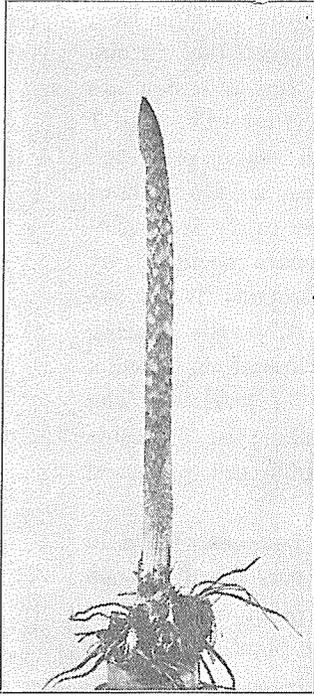
Vegetative shoots. The vegetative shoot is provided with two radical foliage leaves and a scape, grown from the axil of the upper foliage leaf (Text Fig. 4). The axilar bud of the lower foliage leaf, however, is destined to differentiate itself as the apical bud in the next vegetative period, unlike the axilar buds of the bracts which are to become cormlets in the same season. The spadix (Plate IV, Fig. 1 and Fig. 16) is situated at the terminal region of a scape, protected by a tubular spathe. The female flower is apetalous, sessile without any rudimental andraecium (Plate IV, Fig. 2). The ovary is single-carpelled, oblong-ovoid, 3 mm by 2 mm, with one locule occupied by a short flattened placenta upon which 7 to 10 orthotropous ovules are borne (Plate IV, Fig. 3). The style is very short, or subsessile bearing generally three stigmas. The male flower is also apetalous, sessile, without any rudimental gynaeceum (Plate IV, Figs. 17 and 18). The stamens are usually three, but sometimes four, in number; the filaments are connated to a single, stout, short column, on which are produced six or eight pollen sacs.

In this species, there is little organ dimorphism between the male and female plant except in the floral organs. However, the difference of size is conspicuous between the two, the female plant being taller and its foliage leaves larger than those of the male plant, so that it is not very difficult to judge the sex of a plant from a distance, if one is trained to discriminate between them.

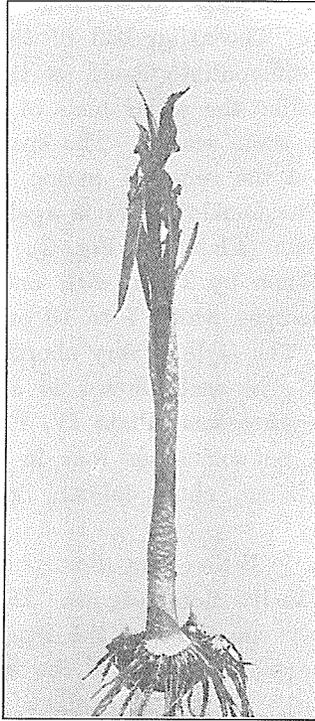
2. Ecological Aspects.

During its experimental cultivation, this plant grew very well under normal conditions. Corms were collected at the end of the vegetative period and preserved in a cold dry place during the winter without fear of any physiological harm for the coming vegetative growth, because, unlike the *Narcissus* and some other garden bulbs, the corms bring forth no roots until spring time. They were planted in field plots as soon as the snow had melted away. After ten days or more, the apical bud and the roots began to grow.

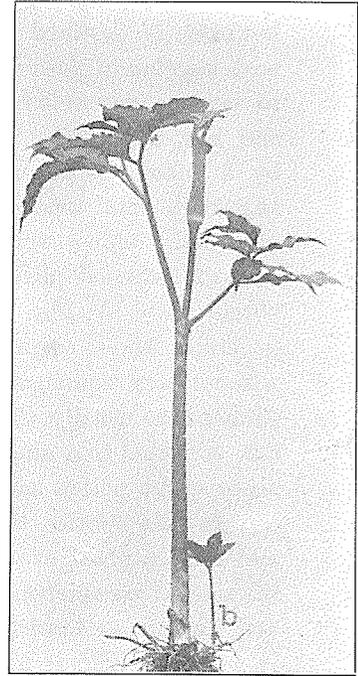
I distinguished three stages in their vegetative growth. The first vegetative stage comprises the period from the sprouting of the apical bud up to the time when the scape attains a certain height (generally 50-60 cm in the female and about 10 cm in the male), and when the spadix and leaf blades begin to break out of the protecting bracts (Text-fig. 2); the second vegetative stage comprises the short



Text-fig. 2. A plant in the 1st vegetative stage.



Text-fig. 3. A plant in the 2nd vegetative stage.



Text-fig. 4. A plant in the 3rd vegetative stage.

period when the leaves finish unfolding their blades after they have come out of the protecting bracts (Text-fig. 3); and the third vegetative stage comprises the rest of the whole vegetative life until the corm closes its growth in the fall (Text-fig. 4). At the beginning of the third vegetative stage, the plant enters the period of vigorous assimilation cooperating with the activity of the fully elongated roots; and shortly afterward the plant attains the maximum growth, generally in the latter half of May, when the gynaecium and andraecium are fully ripened.

The materials consumed to build up these vegetative organs are supplied mainly from the peripheral portion of the reserve tissue of the corm. As a consequence, we see in its longitudinal section remarkable changes in the subepidermal tissue which turns very porous and pulpified, and also the formation of a new cork layer under the decaying tissue thereby shutting it off from the healthy corm body. The

assimilation products formed during the season are transported into and accumulated mostly in the central part of the corm, so that it is very interesting to notice that the corm of the year is not solely a product of the vegetative shoot of that year like that of some of other bulbs, but it is made up from the remaining storage tissues of the preceding years together with the newly formed ones of the year.

Several daughter cormlets, attached to the mother corm, are set free almost simultaneously when the subepidermal tissue contents are consumed for new organ formation. Those larger cormlets which have a foliage leaf *Anlage* in the apical buds are able to follow a further vegetative development, but those smaller ones which are still devoid of the leaf *Anlage* remain dormant and will run to decay. It is characteristic of the young plants to have only one foliage leaf bearing no scape.

I have divided the growing period of the plant into three vegetative stages. The third vegetative stage can also be subdivided into three periods. In the first period of the third stage the leaves are unfolded, in the second period the vegetative activity of the organs is most vigorous, and in the third period the vegetative shoot begins to decay. Now it is important to know in what vegetative stage the corm begins to increase its weight, and in what stage the sex is apparently determined. The following table answers the first question clearly.

Table I.

Showing the Stage in which the Corms begin to increase their Weight (in Grams).

Date	No. of Corm	Remarks	1919 The Weight of			1918 Weight of Corm	Differ
			Corm	Leaves & Scape	Roots		
19/V	24	♀3rd Stage	185.0	125.0	45.0	220.0	-35.0
21/V	68	♀3rd Stage, 1st Period	170.0	203.0	43.0	215.0	-45.0
28/V	4	♀3rd Stage, 1st Period	175.0	205.0	30.0	196.0	-21.0
5/VI	8	♀3rd Stage, 2nd Period	150.0	424.0	35.0	262.0	-112.0
14/VI	85	♀3rd Stage, 2nd Period	133.0	456.0	32.0	204.0	-71.0
16/VI	95	♀3rd Stage, 2nd Period	172.0	282.0	37.0	190.0	-18.0
16/VI	A	♂3rd Stage, 2nd Period	5.0	8.5	4.0	6.0-8.0	
24/VI	6	♀3rd Stage, 2nd Period	163.0	344.0	57.0	182.0	-19.0
"	29	♀3rd Stage, 2nd Period	189.0	298.0	41.0	218.0	-29.0
"	B	♂3rd Stage, 2nd Period	6.0	80.0	40.0	6.0-8.0	
"	C	♂3rd Stage, 2nd Period	5.0	10.0	2.5	6.0-8.0	
9/VII	32	♀3rd Stage, 2nd Period	165.0	334.0	58.0	101.0	+64.0
"	78	♀3rd Stage, 2nd Period	207.0	321.0	40.0	189.0	+18.0
"	D	♀3rd Stage, 2nd Period	8.0	11.0	5.0	6.0-8.0	
"	E	♂3rd Stage, 2nd Period	9.0	10.0	5.0	6.0-8.0	
17/VII	7	♀3rd Stage, 2nd Period	208.0	354.0	39.0	204.0	+4.0
"	12	♀3rd Stage, 2nd Period	231.0	284.0	44.0	208.0	+23.0
"	F	♂3rd Stage, 3rd Period	10.0	6.0	1.5	6.0-8.0	
"	G	♂3rd Stage, 3rd Period	15.0	11.0	3.0	6.0-8.0	
20/VII	H	♂3rd Stage, 3rd Period	11.0	8.0	5.0	6.0-8.0	
"	I	♂3rd Stage, 3rd Period	14.0	12.0	6.0	6.0-8.0	
"	205	♀3rd Stage, 2nd Period	195.0	245.0	70.0	181.0	+14.0
"	36	♀3rd Stage, 2nd Period	272.0	321.0	81.0	224.0	+48.0
24/VII	80	♀3rd Stage, 2nd Period	197.0	136.0	20.0	162.0	+35.0
"	61	♀3rd Stage, 2nd Period	156.0	234.0	58.0	160.0	-4.0
"	51	♀3rd Stage, 2nd Period	272.0	506.0	36.0	271.0	+1.0
"	J	♂3rd Stage, 3rd Period	11.5	9.0	5.0	6.0-8.0	
"	K	♂3rd Stage, 3rd Period	12.5	10.0	5.0	6.0-8.0	
9/VIII	71	♀3rd Stage, 2nd Period	229.0	289.0	41.0	169.0	+60.0
"	60	♀3rd Stage, 2nd Period	180.0	214.0	35.0	162.0	+18.0
"	105	♀3rd Stage, 2nd Period	172.0	305.0	45.0		
"	49	♀3rd Stage, 2nd Period	227.0	563.0	76.0	169.0	+58.0
"	L	♂3rd Stage, 3rd Period	19.0	10.0	3.0	6.0-8.0	
"	M	♂3rd Stage, 3rd Period	17.0	9.0	5.0	6.0-8.0	
"	N	♂3rd Stage, 3rd Period	15.0	9.0	4.0	6.0-8.0	
23/IX	88	♀3rd Stage, 3rd Period	216.0		15.0	176.0	+40.0
"	O	♂3rd Stage, 3rd Period	16.0		1.0	6.0-8.0	
"	P	♂3rd Stage, 3rd Period	18.0		1.0	6.0-8.0	

As is seen in the above table, the weight increase of the male and female corms begins in the beginning of June when the apex of the spathe has begun to turn yellow.

Anatomically the *Anlage* of an apical bud is, at first, composed of no more than a few slightly differentiated rudimentary bracts (Plate IV, Fig. 15). By the subsequent differentiation, the bracts increase in number up to eight or nine when the incipient spadix and spathe begin to be seen. The incipient spadix is smooth at first (Plate IV, Figs. 11, 12, 13, and 25), but afterwards slight cellular processes are thickly formed upon its surface (Plate IV, Fig. 10). The sex differentiation appears during the second period of the third vegetative stage from the latter half of July to August (Plate IV, Figs. 7, 8, 9, 20, 21, 23, and 24), when the weight of the corm is rapidly increasing, and we see that the surplus quantity of assimilation products plays an important rôle on the sex differentiation.

3. Summary.

1. The corm awakes in early spring from its resting stage and reaches the full development of its vegetative growth about a month later at the cost of the reserve material stored in its subepidermal portion. This peripheral tissue becomes porous and pulpified and is delimited by a newly formed cork layer from the rest of the still sound portion of the corm. In this way, the mother corm may survive for many years.

2. Cormlets formed on the mother corm are asexual with one foliage leaf.

3. The sexual corm has two foliage leaves and one scape.

4. From the sexual point of view, this plant can be divided in three states; that is, the asexual, the male, and the female state.

5. The increase of the corm weight begins about the beginning of July, when the shoot attains its maximum development.

6. The apical bud of a corm begins to be formed, generally, during the first part of July in the first period of the third vegetative stage.

7. The sex of the corm is determined during a period reaching from the latter half of July to August in the second period of the third vegetative stage of the year, about a month later than the period when the shoot attains its maximum growth.

II. Experimental Observation on the Transformation of the Sexual State of *Arisaema japonica* Bl.

1. Method.

The corms used for observation were planted in the experimental plots in the Botanic Garden of the Hokkaido Imperial University. The plots were first well tilled and levelled and then the numbered corms planted about 40 cm apart and 10 cm deep. The preservation of the corms during the winter required much care. The corms dug from the field plot were carefully examined, and all the cornlets taken off. Every wounded or rotted portion was neatly cut away. They were moderately dried, put in numbered paper bags, and preserved in a dry cool place. No special fertilizers have been used. But the soil was sufficiently cultivated, and a dressing of well rotted compost was applied at the time of planting the corms. This treatment was not only fairly sufficient to meet the plant requirements, but was very convenient to keep the fertility of the soil in as uniform a condition as possible during several years.

The experimental field plots are situated in an unsheltered sunny place. It is undoubtedly due to these favourable conditions of soil, air, and sunlight that there are many large corms to be found in these plots such as are never met with in nature.

2. Cases and Percentages of Sex Transformations in the Observed Corms.

At the outset of the investigations, it is important to ascertain the fact of sex transformation in this plant and to gather as much knowledge concerning it as possible. For this purpose, I repeated the cultivation of the male, female, and asexual corms for several years and compared the sex of the same corm with that of the previous year.

Table II.

Cases of Sex Transformation observed in 1917 and 1918.

Years		Corm Numbers											Sum	
1917	1918	4	5	6	7	8	10	11	14	16	17	18		19
♀	♀	21	22	23	25	26	27	33	35	36	38	40	41	47
		44	45	47	48	49	50	51	61	63	69	71	77	
		80	82	86	88	89	95	96	97	98	100	101		

Table V.
Cases of Sex Transformation observed in 1920-1921.

Years		Corm Numbers												Sum
1920	1921	5	11	15	16	21	30	35	39	44	46	58	59	
♀	♀	62	65	69	83	84	87	108	109	117	119	121	127	55
		130	131	143	145	154	159	160	165	172	176	180	184	
		185	188	192	195	196	198	201	203	207	212	218	221	
		222	406	409	425	426	427	507						
♀	Asex.	0												0
♀	♂	204	645											2
♂	♀	153	155	220	223	407	408	411	412	414	415	416	417	57
		421	423	458	459	461	462	465	468	469	473	476	485	
		486	492	496	509	512	513	516	517	518	519	520	521	
		522	523	524	525	531	535	536	541	552	553	559	560	
		567	570	582	595	597	621	629	632	636				
♂	♂	76	111	439	440	441	446	450	455	463	470	478	482	75
		490	493	499	500	508	538	539	540	542	543	544	545	
		546	549	550	554	556	557	562	568	571	572	573	575	
		576	579	583	584	585	587	588	589	590	591	593	594	
		596	598	599	600	601	602	613	614	616	617	618	619	
		620	622	623	624	627	628	633	634	635	637	638	639	
		640	641	642										
♂	Asex.	115	438	495	551	644								5
Total Sum		Observed ♀ corms 57												194
		Observed ♂ corms 137												

Table VI.
Cases of Sex Transformation observed in 1918-1919.

Years		Corm Numbers												Sum
1918	1919	613	614	615	616	617	618	619	620	621	622	623	624	
Asex.	Asex.	625	626	627	628	629	630	631	632					20
Asex.	♂	588	589	590	591	592	593	594	595	596	597	598	599	14
		601	602											
Asex.	♀	0												0
Total Sum														34

In the second table, it is shown that among 57 male corms of the preceding year, 54 corms (94.7%) transformed their sex to the female state the next year. This table shows very clearly that the sex transformation is absolutely limited to the male corms, no female corms changing to the other sexual state.

In the third table, it is interesting to notice that the corms No. 76, 218, and 227 which had remained in the male sex in 1918, as seen

in the second table, were all transformed into the female state. Among 95 females, 93 corms (97.9%) remained in the same sex and the other 2 corms (2.1%) were transformed reversely to the male state.

In the fourth table, among 17 male corms 13 (76.4%) were transformed into the female state and the remaining 4 remained in the same sex, while all the female corms remained so except one which was reversed into the male state.

In the fifth table, I was able to observe with more clearness the process of sex transformation of the male corms. The material of the male corms was selected from the complemental plots wherein asexual cormlets, divided from female corms, had been nursed since 1918. In this group 55 female corms (96.4%) remained in the same sex, and the remaining two corms (3.6%) changed into the male state. Among 137 male corms, 75 (54.7%) remained in the same sex, and 57 (41.6%) were transformed into females, but the remaining 5 (3.7%) were reversed into the asexual state.

In the sixth table, cases of sex transformation of asexual corms only are given. Among 34 asexual corms, 20 (58.8%) remained in the same sex and the rest (41.2%) were transformed into the male state. There were found no cases of transformation from the asexual to the female state.

From the mathematical point of view, we can expect nine possible cases of sex transformations in this plant. Takeda (1906, p. 329) reported four cases of sex transformation in *Arisaema ringens*. His observation of *Arisaema ringens* var. *Sieboldii* was started in 1901 on two male corms which had been female in the previous year. The cases of transformation in this plant were (1) from female to male, (2) from male to female, (3) from male to male, and (4) from male to asexual. The writer observed 7 cases of sex transformation in *Arisaema japonica* as shown in Table VII.

Table VII.
Cases of Sex Transformation in *Arisaema japonica*.

1st year	2nd year	Number	Total
Asex.	Asex.	20 (in Table VI)	20
Asex.	♂	14 (in Table VI)	14
Asex.	♀	0	0
♂	♂	3 (in Table II), 75 (in Table V).	82
♂	Asex.	5 (in Table V)	

♂	♀	54 (in Table II), 13 (in Table IV),	5 (in Table III), 57 (in Table V).	129
♀	♀	47 (in Table II), 54 (in Table IV),	93 (in Table III), 55 (in Table V).	249
♀	♂	2 (in Table III), 2 (in Table V).	1 (in Table IV).	5
♀	Asex.	0		0
Total				504

It is meaningless to place importance on the frequency of sex transformation contained in the above table, for neither the age of the corms of the same sex, nor the number of the corms of each sex were equal. But I can say from the above data that:—

1. The transformation of the sexual state is almost limited to the male and asexual corms.
2. Most of the male corms transform into the female state, and the asexual corms change into the male state.
3. but some of the male and asexual corms remain in the same sex.
4. Some few male corms, however, are reversed into the asexual state.
5. Contrary to the male corms, almost all female corms remain in the same sex.
6. but rarely, a few female corms are reversed into the male state.
7. No case is found that female corms are reversed into the asexual state nor asexual corms transformed into the female state.

3. On the "Process of Sex Transition" in *Arisaema japonica* Bl.

In the following tables the sexual records of the corms extending from three to five years are shown.

Table VIII.

Showing the Process of Sex Transition of Large Corms
in Normal Soil Condition for Three to Five Years.

No.	1917	1918	1919	1920	1921	No.	1917	1918	1919	1920	1921
1	—	♀	♀	—	—	8	♀	♀	♀	—	—
2	♂	♀	♀	—	—	9	♂	♀	♀	—	—
3	—	♀	♀	♂	—	10	♀	♀	♀	—	—
4	♀	♀	♀	—	—	11	♀	♀	♀	♀	♀
5	♀	♀	♀	♀	♀	12	♂	♀	♀	—	—
6	♀	♀	♀	—	—	15	—	—	♀	♀	♀
7	♀	♀	♀	—	—	16	♀	♀	♀	♀	♀

No.	1917	1918	1919	1920	1921	No.	1917	1918	1919	1920	1921
17	♀	♀	♀	—	—	69	♀	♀	♀	♀	♀
18	♀	♀	♀	—	—	70	♂	♀	♀	—	—
19	♀	♀	♀	—	—	71	♀	♀	♀	—	—
20	♂	♀	♂	—	—	72	♂	♀	♀	—	—
21	♀	♀	♀	♀	♀	73	♂	♀	♀	—	—
22	♀	♀	♀	—	—	75	—	♀	♀	—	—
23	♀	♀	♀	—	—	76	♂	♂	♀	—	—
24	♂	♀	♀	—	—	77	♀	♀	♀	—	—
25	♀	♀	♀	—	—	78	♂	♀	♀	—	—
26	♀	♀	♀	—	—	79	♂	♀	♀	♀	—
27	♂	♀	♀	♀	♀	80	♂	♀	♀	—	—
28	♂	♀	♀	—	—	81	♂	♀	♀	♀	—
29	♂	♀	♀	—	—	83	♂	♀	♀	♀	♀
30	♂	—	♀	♀	♀	84	♂	♀	♀	♀	♀
31	♂	♀	♀	—	—	85	♂	♀	♀	—	—
33	♀	♀	♀	♀	—	86	♀	♀	♀	♀	—
35	♀	♀	♀	♀	♀	87	♂	♀	♀	♀	♀
36	♀	♀	♀	—	—	88	♀	♀	♀	—	—
37	♂	♀	♀	♀	—	89	♀	♀	♀	—	—
38	♀	♀	♀	—	—	90	♂	♀	♀	—	—
39	—	—	♂	♀	♀	91	—	♀	♀	♀	—
42	—	♂	♀	—	—	92	♂	♀	♀	—	—
43	♂	♀	♀	—	—	93	♂	♀	♀	—	♀
44	♀	♀	♀	♀	♀	94	—	♀	♀	—	—
45	♀	♀	♀	—	—	95	♀	♀	♀	—	—
46	Asex.	♂	♀	♀	♀	96	♀	♀	♀	—	—
47	♀	♀	♀	—	—	97	♀	♀	♀	—	—
48	♀	♀	♀	—	—	98	♀	♀	♀	—	—
49	♀	♀	♀	—	—	205	♂	♀	♀	—	—
50	♀	♀	♀	—	—	206	♂	♀	♀	—	—
51	♀	♀	♀	—	—	207	♂	♀	♀	♀	♀
52	♂	♀	♀	♀	—	208	♂	♀	♀	—	—
53	♂	♀	♀	—	—	209	♂	♀	♀	—	—
54	♂	♀	♀	—	—	211	♂	♀	♀	—	—
55	—	♀	♀	—	—	212	♂	♀	♀	♀	♀
56	♂	♀	♀	—	—	213	♂	♀	♀	—	—
57	♂	♀	♀	—	—	214	♂	♀	♀	—	—
58	Asex.	♂	♀	♀	♀	215	♂	♀	♂	—	—
59	♂	♀	♀	♀	♀	216	♂	♀	♀	—	—
60	♂	♀	♀	—	—	218	♂	♂	—	♀	♀
61	♀	♀	♀	—	—	220	—	—	♂	♂	♀
62	♂	♀	♀	♀	♀	221	—	♀	♀	♀	♀
63	♀	♀	♀	—	—	222	♂	♀	♀	♀	♀
65	♂	♀	♀	♀	♀	224	♂	♀	♀	—	—
66	♂	♀	—	♀	—	225	♂	♀	♀	—	—
67	♂	♀	♀	—	—	226	♂	♀	♀	—	—
68	♂	♀	♀	—	—	227	♂	♂	♀	♀	—

Table IX.

Showing the Process of Sex Transition of Small Corms
in Normal Soil Condition for Four Years.

No.	1918	1919	1920	1921	No.	1918	1919	1920	1921
538	Asex.	♂	♂	♂	571	Asex.	♂	♂	♂
539	Asex.	♂	♂	♂	572	Asex.	♂	♂	♂
540	Asex.	♂	♂	♂	573	Asex.	♂	♂	♂
541	Asex.	♂	♂	♀	574	Asex.	♂	♀	—
542	Asex.	♂	♂	♂	575	Asex.	♂	♂	♂
543	Asex.	♂	♂	♂	576	Asex.	♂	♂	♂
544	Asex.	♂	♂	♂	577	Asex.	♂	♀	—
545	Asex.	♂	♂	♂	578	Asex.	♂	♂	—
546	Asex.	♂	♂	♂	579	Asex.	♂	♂	♂
547	Asex.	♂	♂	—	580	Asex.	♂	♂	—
548	Asex.	♂	♂	—	581	Asex.	♂	♂	—
549	Asex.	♂	♂	♂	582	Asex.	♂	♂	♀
550	Asex.	♂	♂	♂	583	Asex.	♂	♂	♂
551	Asex.	♂	♂	Asex.	584	Asex.	♂	♂	♂
552	Asex.	♂	♂	♀	585	Asex.	♂	♂	♂
553	Asex.	♂	♂	—	586	Asex.	♂	♂	—
554	Asex.	♂	♂	♂	587	Asex.	♂	♂	♂
555	Asex.	♂	♀	—	588	Asex.	♂	♂	♂
556	Asex.	♂	♂	♂	589	Asex.	♂	♂	♂
557	Asex.	♂	♂	♂	590	Asex.	♂	♂	♂
558	Asex.	♂	♀	—	591	Asex.	♂	♂	♂
559	Asex.	♂	♂	♀	592	Asex.	♂	♂	—
560	Asex.	♂	♂	♀	593	Asex.	♂	♂	♂
561	Asex.	♂	♂	—	594	Asex.	♂	♂	♂
562	Asex.	♂	♂	♂	595	Asex.	♂	♂	♀
563	Asex.	♂	♀	—	596	Asex.	♂	♂	♂
564	Asex.	♂	♀	—	597	Asex.	♂	♂	♀
565	Asex.	♂	♀	—	598	Asex.	♂	♂	♂
566	Asex.	♂	♂	—	599	Asex.	♂	♂	♂
567	Asex.	♂	♂	♀	600	Asex.	♂	♂	♂
568	Asex.	♂	♂	♂	601	Asex.	♂	♂	♂
569	Asex.	♂	♀	—	602	Asex.	♂	♂	♂
570	Asex.	♂	♂	♀					

Table X.

Showing the Process of Sex Transition of Very Small Corms in Normal Soil Condition for Four Years.

No.	1918	1919	1920	1921	No.	1918	1919	1920	1921
613	Asex.	Asex.	♂	♂	630	Asex.	Asex.	♂	—
614	Asex.	Asex.	♂	♂	631	Asex.	Asex.	♂	—
615	Asex.	Asex.	♂	—	632	Asex.	Asex.	♂	♂
616	Asex.	Asex.	♂	♂	633	Asex.	Asex.	♂	♀
617	Asex.	Asex.	♂	♂	634	Asex.	Asex.	♂	♂
618	Asex.	Asex.	♂	♂	635	Asex.	Asex.	♂	♂
619	Asex.	Asex.	♂	♂	636	Asex.	Asex.	♂	♂
620	Asex.	Asex.	♂	♂	637	Asex.	Asex.	♂	♀
621	Asex.	Asex.	♂	♀	638	Asex.	Asex.	♂	♂
622	Asex.	Asex.	♂	♂	639	Asex.	Asex.	♂	♂
623	Asex.	Asex.	♂	♂	640	Asex.	Asex.	♂	♂
624	Asex.	Asex.	♂	♂	641	Asex.	Asex.	♂	♂
625	Asex.	Asex.	♂	—	642	Asex.	Asex.	♂	♂
626	Asex.	Asex.	♂	—	643	Asex.	Asex.	♂	♀
627	Asex.	Asex.	♂	♂	644	Asex.	Asex.	♂	—
628	Asex.	Asex.	♂	♂					
629	Asex.	Asex.	♂	♂					
					Total				32

These data represent the entire record of the corms which I have cultivated under experimental observation since 1917. The corms of lacking numbers were eliminated for various reasons.

One hundred and two corms, from No. 103 to No. 204, were cultivated in sandbeds in 1917 and 1918, and Nos. 13, 14, 32, 34, 40, 41, 64, 74, 82, 99, 100, 101, 102, 210, 217, 219, and 223 had to be eliminated on account of parasitic or physiological diseases or because they were used by the author for anatomical purposes.

In these tables, we cannot overlook the fact that the sexual transformation of the corms takes place generally in quite a regular way. Fifty males, in 1917, were transformed to the female state the next year (Nos. 2, 9, 12, 20, 24, 28, 29, 31, 37, 43, 52, 53, 54, 56, 57, 59, 60, 62, 65, 66, 67, 68, 70, 72, 73, 78, 79, 81, 83, 84, 85, 87, 90, 92, 93, 205, 206, 207, 208, 209, 211, 212, 213, 214, 215, 216, 222, 224, 225, and 226). In the third or fourth year, the corms No. 76, No. 218, and No. 227 were transformed into female corms. Thus, all the males completely changed their sex into the female state, so that it can be said that the male corms are undoubtedly fated, sooner or later, to transform into the female state.

It is also very conspicuous that the female corms remain in the

same sex for years as long as they live in a normal condition. Nos. 5, 11, 16, 21, 27, 33, 35, 44, 59, 62, 65, 69, 83, 84, 86, 87, 207, 212, 221, and 222 remained in the female state for four years or more. Corms No. 46, and No. 58 had been asexual in 1917. They transformed into males the next year, in the third year they were changed into the female state, and since then (1919) they have remained in the same sex.

In the late fall of 1918, the writer had a great many asexual cormlets derived from female corms. They were divided in three groups (large, medium, and small) and carefully planted in separate garden plots. In the first year after planting, none of the groups gave any sexual corms, but in the second year (Table IX) the group consisting of large sized cormlets gave 65 sexual corms, in the third year (Table X), another group, consisting of medium sized cormlets, gave 32 male corms, and lastly, in the fourth year, a few male corms were produced in the group consisting of the small sized cormlets. Those corms in which the sexual transformation had taken place, were carefully transplanted to prepared new beds wherein their further sexual records were observed, as shown in the above tables. We can see from these tables that most cormlets divided from the mother corms stay at least a year in the asexual state and then invariably enter into the sexual state as male corms.

From the preceding tables we can see that there is no case of sex reversion of the female corms into the asexual state, nor of the asexual corms into the sexual state as female corms. It is, therefore, very reasonable to think that the male sex is the intermediate stage between the asexual and female state. It is also very probable that the course of sex transformation in *Arisaema japonica* is definitely destined to proceed from the asexual state to the male state and then from the male to the female state, where the sex remains unchanged as long as the corm follows its normal development. This process of sex transformation, we wish to designate as the "Phenomenon of Sex Transition". It proves that the sexuality of *Arisaema japonica*, which has been considered as a dioecious plant, is not determined as female or male from the embryonal stage, but the sex transition takes place in the course of the development of the plant, the male state being no more than a mere transitional stage of the corm to reach the female state.

4. Summary.

1. The phenomenon of sex transition is the potentially predetermined process of sex transformation in *Arisaema japonica*.

2. The dioecious condition of *Arisaema japonica* is not initially a predetermined condition of sex tendency, but only an apparent condition consisting of sexual corms in various stages of the sex transition process.

III. On the Influence of Sandbed Cultivation on the Phenomenon of Sex Transition.

In the preceding chapter, the writer has shown that the course of sex transformation is potentially predetermined in the process of sex transition. It will be, now, interesting to test the tenacity of this phenomenon under an extreme condition of life. For this purpose, the writer has chosen the sandbed cultivation.

1. Method.

The sandbeds were prepared 0.5 m deep and 0.7 m wide. The bottom of the beds was beaten down hard, and the sides were enclosed tightly with thick boards. The beds were filled with fine river sand free from loam. In these beds the corms were planted 10 cm x 30 cm apart, and about 10 cm deep. In this way quite a sterile and dry condition was acquired.

2. On the Effect of Sandbed Cultivation on the Cases of Sex Transformation.

In these beds, 102 corms (from No. 103 to No. 204) were planted. However, some loss of corms was unavoidable under the extreme cultural conditions, so that several corms died or produced deformed buds.

Table XI.

Cases of Sex Transformation in Sandbed Cultivation in the First Years.

Years		Corm Numbers								Sum
1917	1918	104	105	106	107	108	110	112	113	40
♀	♀	118	119	121	122	123	125	126	127	
		128	129	130	132	133	134	135	147	

		158	173	177	178	179	182	183	185	
		186	188	189	191	193	198	199	200	
♀	♂	115	192							2
♀	Asex.	0								0
♂	♂	137	142	156	159	160	163	176	172	12
		180	196	203	204					
♂	♀	109	114	116	120	136	144	150	154	19
		164	165	166	167	171	175	176	181	
		187	190	197						
♂	Asex.	0								0
Total	Observed ♀ corms									42
	Observed ♂ corms									31
										73

In Table XI, the greater number of female corms (95.2%) remained in the same sex, and only 4.8% of them reversed into the male sex. Among 31 male corms, 19 corms (61.3%) transformed into the female state, and the rest remained in the same sex. All these male and female corms were again planted in the same beds the next year (1918), as it was expected that the influence of sandbed cultivation would be impressed more markedly in this way (Table XII).

Table XII.

Cases of Sex Transformation in Sandbed Cultivation in the Second Year.

Years		Corm Numbers								Sum
1918	1919									
♀	♀	103	104	105	106	107	108	109	110	47
		112	113	114	119	120	121	122	123	
		125	126	127	128	130	132	133	134	
		135	136	139	147	150	154	158	164	
		165	166	167	171	173	175	182	185	
		186	187	189	191	193	198	201		
♀	♂	116	129	174	176	181	188	197		7
♀	Monoecious	195								1
♀	Asex.	0								0
♂	♂	115	155	163	170	180	184	196	203	9
		204								
♂	♀	117	131	137	142	143	156	159	160	10
		172	192							
♂	Asex.	0								0
Total Sum	Observed ♀ corms									55
	Observed ♂ corms									19
										74

Forty-seven female corms (85.5%), in the above table, remained in the same sex, seven corms (12.7%) reversed into the male sex, and the remaining one (1.8%) formed a monoecious inflorescence. Nine

male corms (47.3%) remained in the same sex, and the remaining ten corms (52.7%) transformed into the female state. Thus, the continued cultivation in the sandbed increased the rate of reversion into female corms.

For the sake of comparison, the frequency of one hundred and forty-seven cases of sex transformation contained in the above two tables are summarized in the following Table, XIII.

Table XIII.
Summarized Table of the Cases of Sex Transformation
in Sandbed Cultivation.

1st year	2nd year	Numbers		Sum
♀	♀	40 (in Table XI),	47 (in Table XII).	87
♀	♂	2 (in Table XI),	7 (in Table XII).	9
♀	Monococious	1 (in Table XII)		1
♀	Asex.	0		0
♂	♂	12 (in Table XI),	9 (in Table XII).	21
♂	♀	19 (in Table XI),	10 (in Table XII).	29
♂	Asex.	0		0
Total				147

As shown in Table XIII, the cases of sex constancy, and the cases of change from female to male, from male to female, and from female to monoecious were also found in the normal garden soil cultivation. In the latter case of cultivation, there were also observed cases of transformation from male to asexual, from asexual to male, and stability in the asexual state, which we failed to find in the sandbed cultivation, but these cases must certainly be found if young male and asexual corms are used in the cultivation.

It is very interesting to know from the above observations, that the rate of sex transformation from one sex to another is reduced a little by the sandbed cultivation. The whole number of female corms in the Table II remained in the same sex, while two females (4.8%) out of forty-two females in Table XI reversed into the male sex. Fifty-four male corms (94.7%) in Table II transformed into the female sex the next year, while only nineteen corms (61.3%) in Table XI transformed into females. This reduction in the rate of the progressive transformation induced at the same time an increase in the rate of the male sex immutableness. Only three male corms (5.3%) in Table II remained in the same sex in the garden plot cultivation, while 12 male

corms (38.7%) remained in the same sex in the latter case. This correlation is more marked in the case of continued cultivation in sandbeds (Table XII). In Table III, ninety-three female corms (97.9%) remained in the same sex, while in the Table XII forty-seven female corms (85.5%) remained in the same sex. In the garden plot cultivation the male corms which failed to change into the female state (Table II) were transformed into the female state the next year (Table III), so that all the males were changed into females during two years, while in Table XII, still nine corms (47.3%) are left in the same state. This difference is, without any doubt, due to the retarding influence of the sandbed cultivation upon the process of sex transition.

The rate of regressive transformation under the two different ways of cultivation is also different. In the normal garden soil cultivation, Table II, no cases of reversal transformation were found, while in Table XI, there are two cases (4.8%) of reversion of female corms into the male state. In Table III, two cases of reversion (2.1%) of female corms into the male state, and in Table XII, 7 cases of reversion (12.7%) of female corms into the male state are found. This increased rate of reversion may be regarded as a result of the sterile condition of the soil.

The results of the above discussion may be summarized as follows:—

1. The rate of female corms remaining in the same sex under sandbed cultivation is less than in the case of garden soil cultivation.
2. The rate of regressive transformation of female corms in sandbeds is greater than that of female corms cultivated in garden soil.
3. The rate of transformation of male corms into the female sex in sandbeds is less than that of male corms cultivated in garden soil.
4. The rate of male corms, grown in sandbeds, remaining in the same sex is greater than that in the case of garden soil cultivation.
5. The reversal relation in the rate of sex transformation is mainly due to the retardation of the process of sex transition and to the tendency of regression in the course of sex transition.
6. There were found no cases of sex transformation from the female to the asexual state neither in sandbeds nor in normal garden soil.

3. On the Effect of Sandbed Cultivation on the Process of Sex Transition.

It is presumed in the preceding observation that the sterile condition of soil retards the process of sex transition. The following table will tell the relation in detail and will assist us to comprehend how the sterile or fertile condition of soil influences the normal process of sex transition of the plant. In the following Table, XIV, the reader is requested to recognize that the sex of the corms in 1917 had been already determined during their forest life, while their sex in 1918 and 1919 was determined during their sandbed life in 1917 and 1918 respectively.

Table XIV.

Showing the Records of the Sex Transformation of the Corms cultivated in the Sandbed in 1917 and in 1918.

The sex is acquired during existence in					The sex is acquired during existence in				
No.	forest 1917	sandbed 1918 1919		gardenplot 1920 1921	No.	forest 1917	sandbed 1918 1919		gardenplot 1920 1921
103	—	♀	♀	—	129	♀	♀	♂	—
104	♀	♀	♀	—	130	♀	♀	♀	♀
105	♀	♀	♀	—	131	—	♂	♀	♀
106	♀	♀	♀	—	132	♀	♀	♀	—
107	♀	♀	♀	—	133	♀	♀	♀	—
108	♀	♀	♀	♀	134	♀	♀	♀	—
109	♂	♀	♀	♀	135	♀	♀	♀	—
110	♀	♀	♀	—	136	♂	♀	♀	—
111	♂	—	♂	♂	137	♂	♂	♀	—
112	♀	♀	♀	—	139	—	♀	♀	—
113	♀	♀	♀	—	140	—	♀	—	—
114	♂	♀	♀	—	141	—	—	♂	—
115	♀	♂	♂	♂	142	♂	♂	♀	—
116	♂	♀	♂	—	143	—	♂	♀	♀
117	—	♂	♀	♀	144	♂	♀	—	—
118	♀	♀	—	—	145	—	—	♂	♀
119	♀	♀	♀	♀	146	—	—	♂	—
120	♂	♀	♀	—	147	♀	♀	♀	—
121	♀	♀	♀	♀	150	♂	♀	♀	—
122	♀	♀	♀	—	153	—	—	♂	♀
123	♀	♀	♀	—	154	♂	♀	♀	♀
125	♀	♀	♀	—	155	—	♂	♂	♀
126	♀	♀	♀	♀	156	♂	♂	♀	—
127	♀	♀	♀	♀	157	—	—	♀	—
128	♀	♀	♀	—	158	♀	♀	♀	—

The sex is acquired during existence in						The sex is acquired during existence in					
No.	forest 1917	sandbed 1918	1919	gardenplot 1920	1921	No.	forest 1917	sandbed 1918	1919	gardenplot 1920	1921
159	♂	♂	♀	♀	♀	183	♀	♀	—	—	—
160	♂	♂	♀	♀	♀	184	—	♂	♂	♀	♀
163	♂	♂	♂	♀	—	185	♀	♀	♀	♀	♀
164	♂	♀	♀	—	—	186	♀	♀	♀	—	—
165	♂	♀	♀	♀	♀	187	♂	♀	♀	—	—
166	♂	♀	♀	—	—	188	♀	♀	♂	♀	♀
167	♂	♀	♀	—	—	189	♀	♀	♀	—	—
169	—	—	♂	♀	—	191	♀	♀	♀	—	—
170	♂	♂	♂	—	♀	192	♀	♂	♀	♀	♀
171	♂	♀	♀	—	—	193	♀	♀	♀	—	—
172	♂	♂	♀	♀	♀	195	—	♀	♂	♀	♀
173	♀	♀	♀	—	—	196	♂	♂	♂	♀	♀
174	—	♀	♂	—	—	197	♂	♀	♂	—	—
175	♂	♀	♀	♀	—	198	♀	♀	♀	♀	♀
176	♂	♀	♂	♀	♀	199	♀	♀	—	—	—
177	♀	♀	—	—	—	200	♀	♀	—	—	—
178	♀	♀	—	—	—	201	—	♀	♀	♀	♀
179	♀	♀	—	—	—	202	—	—	♀	♀	—
180	♂	♂	♂	♀	♀	203	♂	♂	♂	♀	♀
181	♂	♀	♂	—	—	204	♂	♂	♂	♀	♂
182	♀	♀	♀	—	—						

Generally speaking, 33 individuals, whose sex records were continued until 1921, may be said to have followed their course of sex transition very regularly, yet we see in them all to a more or less degree a retarding influence of the unfavorable soil condition. However, this retarding influence disappeared soon after their transplantation in fertile soil. The result obtained in this experiment shows that the sterile condition does not influence them further than to retard the process of sex transition. Even those corms, which were forced to remain in the male state or those which were reversed into the male state from the female state, recovered promptly their normal behaviour in the first year of transplantation. Those corms, whose recovery was not immediate, recovered their normal process in the course of two or three years after transplantation as in the case of Nos. 153 and 155. Corm No. 204 was reversed once more into the male state in 1921, but were we to continue the experiment longer, we would surely see it come back again to the female state as we have seen in many other examples. Corm No. 111 seems to have been affected very much by the unfavourable nutritive condition, so that the corm was not transformed into the female state even after two years' cultivation

in garden soil. However, we can foretell its future transformation into the female state, if the corm gains in vigor again.

We find an interesting example of the transformation in No. 115. This corm reversed into the male sex in 1917 and since then, until 1920, it remained in the same sex for three years. In 1921, it reversed again into the asexual state. Now we see in this kind of sex transition that the process is quite the reverse to that of the normal course of sex transition. This reversal process of transition, however, meets our expectation very well by the reason that we have found no case of direct transformation of female corms into the asexual state. Therefore, the only way left open to the female corms is to turn back to the asexual state, that is, they should first be reversed into the male state at least in the first year, and then, if the sterile condition is prevailing still upon them, they will be reversed again into the asexual state. From these facts, we may conclude that this reversal course of sex transition is also an inherent process of regressive sex transformation of the plant. I would like to call this mode of sex transformation the "Process of Retro-Transition of Sex" for the sake of distinguishing it from the normal process of sex transition. Therefore, it may be expected that, though we had only few examples of this kind of regressive transition in the females under observation, if they were cultivated in the sterile conditions for more than two years, the majority of the corms will be obliged to take the course of "Retro-Transition of Sex" sooner or later.

4. Summary.

1. Generally speaking, in sandbed cultivation the phenomenon of sex transition takes place regularly,
2. however, the process is retarded in some measure.
3. A case of double reversal transformation of sex is found, and it is named the "Process of Retro-Transition of Sex."
4. A case of the formation of the monoecious inflorescence produced from a female corm of the previous year was found in sandbed cultivation.
5. These data clearly tell that the sexual expression of *Arisaema japonica* is not a fixed character.

IV. On the Relation of Corm Weights and Sex.

The fact that the normal process of sex transition as well as its retardation and also the retro-transition of sex are correlated with the sizes of the corms, reveals us that the degree of the vegetative growth of the plant bears a direct relation upon these phenomena. From this point of view, the author undertook the task to determine the weight of the corms and compare it with their sexual records.

1. Method.

The corms were dug out from the plot in the fall. The cormlets upon them were separated and decayed parts of the roots and basal parts of the petioles were taken away. Each of them was washed and carefully wiped with well dried lint and weighed.

2. On the Weight of Female Corms.

Table XV.

Showing the Weight of Large Sized Female Corms of the First Series weighed in the Autumn of 1918 (in Grams).

No.	Corm Wt.	No.	Corm Wt.	No.	Corm Wt.	No.	Corm Wt.
1	99.5	30	23.0	61	160.0	91	98.0
2	124.5	31	135.0	62	158.0	92	192.0
3	102.5	33	155.0	63	142.0	93	153.0
4	196.0	35	300.0	65	150.0	94	103.0
5	360.0	36	224.0	67	91.0	95	190.0
6	182.0	37	158.0	68	215.0	96	109.0
7	204.0	38	110.0	69	178.0	97	127.0
8	262.5	42	40.0	70	88.0	98	52.0
9	108.0	43	105.0	71	169.0	205	181.0
10	117.0	44	89.0	72	80.0	206	112.0
11	225.0	45	175.0	73	69.0	207	89.0
12	208.0	46	57.0	75	113.0	208	57.0
15	33.0	47	137.0	76	95.0	209	105.0
16	67.0	48	173.0	77	172.0	211	116.0
17	129.0	49	165.0	78	189.0	212	149.0
18	120.0	50	366.0	79	177.0	213	133.0
19	211.0	51	271.0	80	162.0	214	173.0
21	144.0	52	148.0	81	145.0	216	135.0
22	91.0	53	213.0	83	225.0	218	89.0
23	213.0	54	51.0	84	165.0	221	79.0
24	220.0	55	150.0	85	199.0	222	91.0
25	247.0	56	139.0	86	258.0	224	144.0
26	129.0	57	72.0	87	82.0	225	129.0
27	159.0	58	23.0	88	176.0	226	122.0
28	39.0	59	92.0	89	136.0	227	41.0
29	218.0	60	162.0	90	135.0	228	42.0
						Total	104

Table XVI.

Showing the Weight of Large Sized Female Corms of the First Series weighed in the Autumn of 1919 (in Grams).

No.	Corm Wt.	No.	Corm Wt.	No.	Corm Wt.	No.	Corm Wt.
5	338.0	62	264.0	127	128.0	180	38.0
9	77.0	65	190.0	130	137.0	184	50.0
11	340.0	69	233.0	131	103.0	185	107.0
15	80.0	79	211.0	132	121.0	188	59.0
16	156.0	81	197.0	141	70.0	192	80.0
21	201.0	83	225.0	143	103.0	196	62.0
27	219.0	84	191.0	145	50.0	198	147.0
30	46.0	86	320.0	146	50.0	201	117.0
33	281.0	87	140.0	154	169.0	202	138.0
35	410.0	91	212.0	159	117.0	203	39.0
37	302.0	107	166.0	160	120.0	204	43.0
39	56.0	108	58.0	163	43.0	207	138.0
44	149.0	109	116.0	165	158.0	212	213.0
46	134.0	117	53.0	169	56.0	218	46.0
52	217.0	119	90.0	172	99.0	221	135.0
58	73.0	121	92.0	175	126.0	222	129.0
59	166.0	126	124.0	176	38.0	227	95.0
Total							68

Table XVII.

Showing the Weight of Large Sized Female Corms of the First Series weighed in the Autumn of 1920 (in Grams).

No.	Corm Wt.	No.	Corm Wt.	No.	Corm Wt.	No.	Corm Wt.
5	154.0	69	233.0	145	93.0	195	235.0
11	132.0	83	233.0	153	53.0	196	129.0
15	141.0	84	147.0	154	161.0	198	184.0
16	133.0	87	159.0	155	44.0	201	235.0
21	95.0	93	81.0	159	215.0	203	70.0
27	159.0	108	124.0	160	255.0	204	43.0
30	55.5	109	182.0	165	123.0	207	102.0
35	238.0	117	33.0	170	73.0	212	258.0
39	34.0	119	142.0	172	204.0	218	53.0
44	99.5	120	51.0	176	73.0	220	90.0
46	160.0	121	155.0	180	92.0	221	173.0
58	55.5	127	121.0	184	129.0	222	82.0
59	144.0	130	194.0	185	196.0	223	151.0
62	32.0	131	120.0	188	78.0		
65	118.5	143	197.0	192	152.0		
Total							58

All the female corms whose weight had been ascertained every fall since 1918 were grouped in the first series. In Table XV, we find that the minimum weight is 23 gr (Nos. 30 and 58) and the maximum weight 366 gr (No. 50), while the weight of most of the corms in this series stands at more than 100 gr in 1918. In Table XVI, we see that the corm weights in the following year are increased, so that the minimum weight is 38 gr (Nos. 176 and 180), while the maximum reaches 410 gr (No. 35). This corm is the largest I have ever seen during my experiments. However, in the third year, as shown in Table XVII, we find that the minimum weight decreased to 32 gr (No. 62) and the maximum to 258 gr (No. 212), the average weight also was moderately lowered. This decrease may be attributed to the natural decay of the old mother corms, as they begin to fade and die after they have reached a certain culminating point of growth.

Large corms sprout out very strong and large shoots at the expense of an ample supply of reserve materials. The assimilation products prepared by the vigorous shoots generally exceed the capacity for storage in the mother corms, so that on the latter are formed deep and wide fissures in the peripheral older tissues. These fissures expose the inner soft tissues to the bacteria, fungi or animals in the soil. I have often observed that the large corms were badly rotten or that the whole body of the mother corms had rotted away leaving only a few cormlets behind it. By comparing Table XVII with Table XVI, we find a conspicuous decrease in the weight of the following corms, which was caused by the rotting above mentioned:— 184 gr (No. 5), 106 gr (No. 21), 60 gr (No. 27), 49.5 gr (No. 44), 232 gr (No. 62), 71.5 gr (No. 65), 44 gr (No. 84), 35 gr (No. 165), 7 gr (No. 127), 36 gr (No. 207), and 47 gr (No. 222).

The decrease of 22 gr (No. 39), 17.5 gr (No. 58), 22 gr (No. 59), 20 gr (No. 117), and 8 gr (No. 154) was caused by another reason. These corms shot out very weak and slender vegetative organs, so that the assimilation products prepared during the season scarcely replaced the already consumed reserve materials for the organ formations in the spring. Thus, the weights of the old female corms in the first series (Tables XV, XVI, and XVII) have undergone a decrease in different ways, however, we can see in these tables that they generally fluctuate between 410 gr and 23 gr.

The corms belonging to this series consisted mainly of large sized ones, so that the true minimum weight of the female corms cannot

be ascertained from these materials only. For this reason, I selected another series (Series II), consisting mainly of small sized female corms, as seen in Tables XVIII and XIX.

Table XVIII.

Showing the Weight of Small Sized Female Corms of the Second Series weighed in the Autumn of 1919 (in Grams).

No.	Corm Wt.							
406	30.0	426	24.0	434	55.0	507	24.0	
409	31.0	427	29.0	435	43.0	514	16.0	
410	32.0	428	76.0	436	74.0	526	19.0	
413	24.0	429	41.0	503	35.0	529	11.0	
418	20.0	430	65.0	504	26.0	532	17.0	
419	25.0	431	46.0	505	23.0	533	26.0	
425	35.0	432	43.0	506	24.0	534	20.0	
							Total	28

Table XIX.

Showing the Weight of Small Sized Female Corms of the Second Series weighed in the Autumn of 1920 (in Grams).

No.	Corm Wt.							
406	75.0	453	45.0	512	49.0	536	20.0	
407	97.0	459	22.0	513	34.0	541	37.0	
408	93.0	461	33.0	516	29.0	552	16.5	
409	58.0	462	28.5	517	68.0	559	28.0	
411	44.0	463	18.0	518	26.0	560	21.0	
412	102.0	469	43.0	519	34.0	567	42.0	
414	34.0	473	56.5	520	24.0	570	20.0	
415	83.0	476	28.5	521	26.0	582	17.5	
416	55.0	485	23.0	522	33.0	595	24.0	
417	63.0	486	38.5	523	35.0	597	18.5	
421	52.0	492	33.5	524	22.0	621	28.5	
423	37.0	496	19.5	525	54.0	629	18.0	
425	109.0	507	24.0	531	53.0	632	23.0	
426	84.0	509	18.0	535	30.0	636	24.5	
427	62.0						Total	57

In Table XVIII, we find the minimum weight to be 11 gr (No. 529) and the maximum weight 76 gr (No. 428). In Table XIX, we find that the minimum weight is 16.5 gr (No. 552) and the maximum weight 109 gr (No. 425). Therefore, the weight of the female corms in this series varies between 109 and 11 gr. From these facts, we

can conclude that from the corms of more than 11 gr in weight we may expect to have female plants.

3. On the Weight of Male Corms.

Table XX.

Showing the Weight of Male Corms weighed in the
Fall of 1919 (in Grams).

No.	Corm Wt.	No.	Corm Wt.	No.	Corm Wt.	No.	Corm Wt.
111	20.0	443	9.0	479	8.0	512	15.0
115	20.0	446	4.0	481	11.0	513	18.0
153	34.0	450	4.0	482	9.0	516	13.0
155	23.0	455	6.0	484	8.0	517	18.0
220	31.0	458	10.0	485	9.0	518	16.0
407	20.0	459	8.0	486	11.0	519	18.0
408	23.0	461	8.0	488	10.0	520	13.0
411	22.0	462	9.0	489	11.0	521	16.0
412	31.0	463	9.0	490	6.0	522	13.0
414	26.0	465	10.0	492	10.0	523	18.0
415	24.0	466	10.0	493	6.0	524	16.0
416	23.0	467	7.0	495	6.0	525	14.0
417	28.0	468	10.0	496	9.0	528	15.0
420	10.0	469	14.0	499	6.0	531	17.0
421	29.0	470	9.0	500	7.0	535	20.0
423	20.0	471	9.0	501	6.0	536	14.0
438	6.0	473	10.0	508	16.0	537	20.0
439	8.0	476	12.0	509	15.0		
440	8.0	477	10.0	510	15.0		
441	5.0	478	7.0	511	12.0		
						Total	77

Table XXI.

Showing the Weight of Male Corms weighed in the
Fall of 1920 (in Grams).

No.	Corm Wt.						
111	24.0	271	7.0	437	13.5	452	12.5
257	6.5	272	9.0	439	20.5	454	17.0
261	10.0	273	7.0	440	20.5	455	16.0
262	10.0	285	9.5	441	11.0	456	17.5
263	7.0	292	5.0	442	12.0	460	8.5
264	20.0	302	6.0	446	9.0	463	16.0
265	17.0	306	5.5	447	9.0	464	6.0
267	19.0	316	7.0	449	4.5	470	24.5
270	10.0	321	6.5	450	15.0	472	14.0

No.	Corm Wt.	No.	Corm Wt.	No.	Corm Wt.	No.	Corm Wt.
474	7.5	544	11.0	585	11.0	618	17.0
475	17.5	545	16.0	587	14.0	619	14.5
478	24.5	546	11.0	588	10.0	620	21.5
482	12.5	549	13.0	589	11.5	622	10.5
490	16.0	550	18.0	590	18.5	623	11.5
491	20.5	554	16.0	591	8.0	624	22.0
493	14.5	556	17.0	593	13.5	627	9.5
494	18.5	557	14.0	594	12.5	628	7.0
499	15.0	562	22.0	596	18.5	633	11.5
500	16.5	568	17.0	598	20.5	634	15.0
502	7.5	571	20.5	599	14.5	635	15.0
508	21.0	572	14.0	600	11.0	637	14.0
533	19.0	573	13.0	601	18.0	638	7.0
538	17.0	575	24.5	602	7.5	639	6.5
539	15.0	576	8.0	613	21.5	640	10.5
540	17.5	579	13.0	614	21.5	641	15.0
542	11.0	583	17.0	616	18.5	642	19.0
543	14.0	584	18.0	617	21.5		
<i>Total</i>						107	

In Table XX, we find that the minimum weight of the male corms is 4 gr (Nos. 446 and 450) and the maximum 34 gr (No. 153). In Table XXI, we find the minimum weight to be 4.5 gr (No. 449) and the maximum 24.5 gr (Nos. 470, 478, and 575). Therefore, the weight of the male corms of this series fluctuates between 34 gr and 4 gr.

4. On the Weight of Asexual Corms.

The size of asexual corms extends from very minute cormlets to moderately sized ones (about 3 cm in diameter). Extremely small cormlets which fail to produce a foliage leaf generally die without any further development. Sometimes we find a few moderately large cormlets still attached to the mother corms producing male scapes. Thus, there are differences in the degree of their size and their organ development. The material used for the present experiment was limited to those cormlets which bear one foliage leaf, those leafless minute cormlets were not weighed though they are asexual in the strict sense.

Table XXII.

Showing the Weight of Asexual Corms weighed in the Autumn of 1919 (in Grams).

No.	Corm Wt.						
256	5.0	257	4.0	258	6.0	259	6.0
261	5.0	262	4.0	263	4.0	264	4.0

No.	Corm Wt.	No.	Corm Wt.	No.	Corm Wt.	No.	Corm Wt.
265	5.0	288	3.0	311	3.0	338	1.5
266	5.0	289	3.0	312	3.0	346	1.5
267	6.0	290	3.0	313	3.0	348	1.5
268	4.0	291	4.0	314	3.0	372	0.5
269	4.0	292	2.0	315	3.0	377	0.5
270	4.0	293	2.0	316	2.0	396	0.5
271	4.0	294	3.0	317	3.0	442	4.0
272	4.0	295	3.0	318	2.0	445	3.0
273	4.0	296	3.0	319	2.0	447	4.0
274	4.0	297	3.0	320	2.0	449	4.0
275	4.0	298	3.0	321	3.0	452	5.0
276	4.0	299	3.0	322	2.0	454	6.0
277	4.0	300	3.0	323	2.0	456	6.0
278	4.0	301	3.0	324	2.0	457	4.0
279	4.0	302	3.0	325	2.0	460	6.0
280	3.0	303	3.0	326	2.0	472	7.0
281	3.0	304	3.0	328	2.0	475	11.0
282	5.0	305	3.0	329	2.0	480	8.0
283	4.0	306	3.0	330	2.0	487	11.0
284	3.0	307	3.0	331	2.0	491	7.0
285	3.0	308	3.0	333	2.0	494	4.0
286	2.0	309	3.0	334	2.0	497	7.0
287	3.0	310	3.0	335	2.0	520	5.0
						Total	100

Table XXIII.

Showing the Weight of Asexual Corms weighed in the
Autumn of 1920 (in Grams).

No.	Corm Wt.	No.	Corm Wt.	No.	Corm Wt.	No.	Corm Wt.
256	4.5	283	9.5	299	3.0	444	3.5
258	4.5	284	4.5	300	5.5	448	4.5
268	5.0	286	4.0	301	4.5	453	4.0
269	7.0	287	4.0	303	2.0	457	3.0
274	6.5	288	6.5	305	3.5	480	6.0
275	3.0	289	2.5	307	2.5	483	5.5
276	6.5	290	5.5	308	5.0	498	6.5
277	6.5	293	3.5	309	2.0	530	8.0
279	9.0	295	5.5	310	4.0		
281	5.5	297	2.0	319	1.5		
282	4.5	298	3.0	322	2.0		
						Total	41

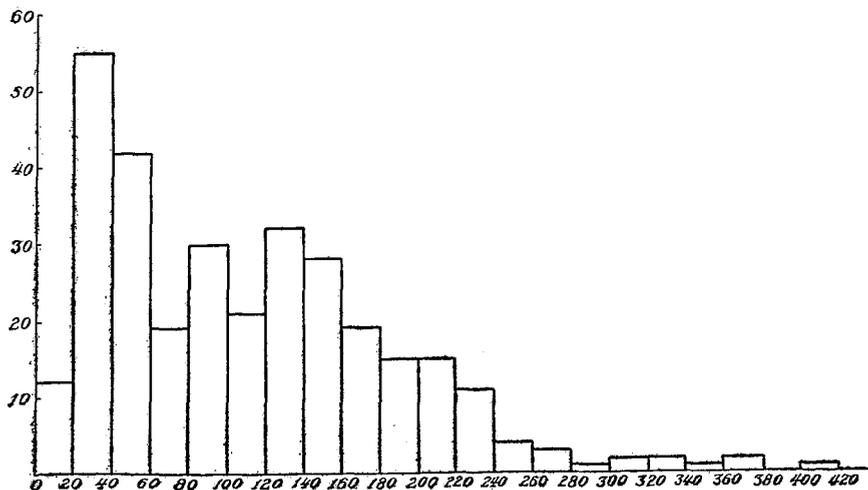
In Table XXII, the minimum weight of the asexual corms is 0.5 gr (Nos. 372, 377, and 396) and the maximum 11 gr (No. 475 and 487). In Table XXIII, the minimum weight is 1.5 gr (No. 319) and the

maximum 9.5 (No. 283). Therefore, we know that the asexual corms weigh generally less than 11 gr, however, the greater number of them are under 4 gr.

5. On the Frequency Distribution of Corm Weights.

In the study of corm weight, we learn that each asexual, male, and female corm has its own weight limits. If a corm grows over its weight limit, it transforms without any exception to a new sexual state proper to its own weight region, as long as the plant is in its normal condition. It is interesting, then, to take up a detailed study of the frequency distribution of the weights of corms together with their common regions occupied by the corms lying outside of the general weight limit. For this purpose three frequency polygons (Text-figs. 5, 6, and 7) are arranged for each sexual state consisting of all the variants contained in Tables XV to XXIII.

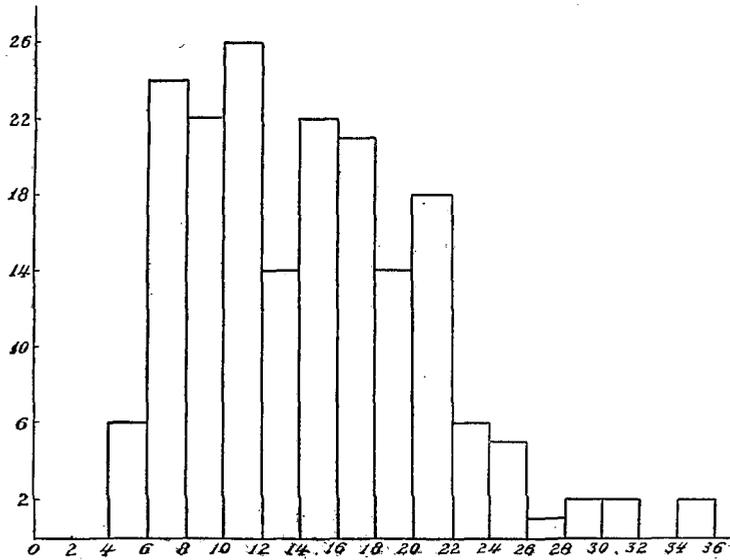
In Text-fig. 5, we see that most of the female corms range from 21 gr upward, and only a very small number of them weigh less than 21 gr. Judging by the process of the sex transition, we can expect that the female variants should be increased in number more and more in the weight region above 21 gr, if there are no natural restrictions of growth upon them. However, we see that in the weight region above 50 gr the female variants become gradually rare in number.



Text-fig. 5. Showing the frequency distribution of corm weights of female corms (Variants 315).

As far as my experience goes, corms weighing above 350 gr are never met with in nature; and even in garden plots, such large corms can be raised only under careful treatment and cultivation.

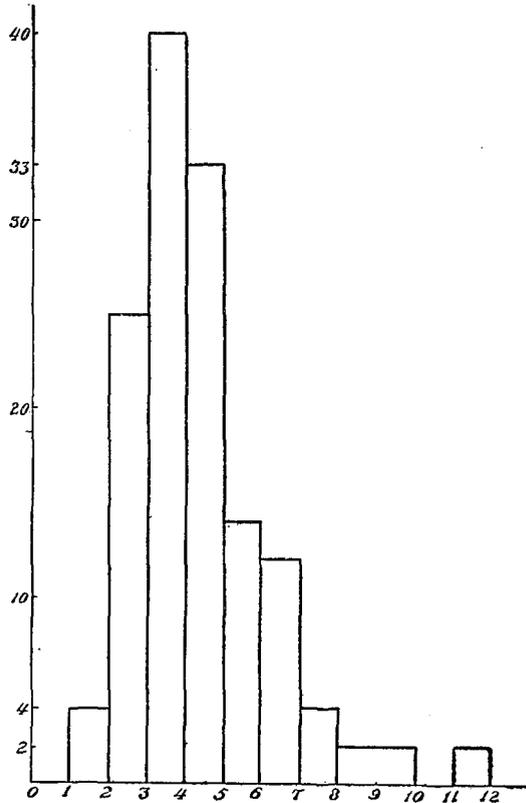
The weight region of male corms lies mostly between 4 gr and 21 gr (Text-fig. 6).



Text-fig. 6. Showing the frequency distribution of corm weights of male corms (Variants 184).

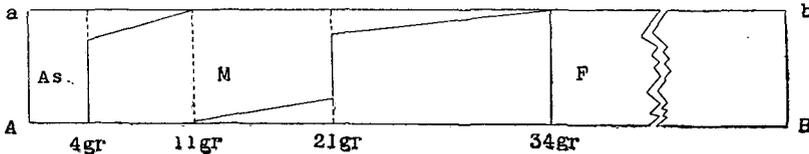
The variants exceeding this upper weight limit are rapidly decreased in number by reason that most of them are transformed into the female state, and the variants under the lower weight limit are generally wanting in sexual expression.

The weight region of the asexual cormlets lies between 0.5 gr and 4.0 gr (Text-fig. 7). Under 0.5 gr, few cormlets are found to display foliage leaves and they remain generally in a dormant stage.



Text-fig. 7. Showing the frequency distribution of corm weights of asexual corms (Variants 141).

Cormlets weighing between 3 gr and 4 gr have a very high rate of sprouting. In Text-fig. 8, a diagrammatic representation of the sexual weight limits is given.



Text-fig. 8. A diagram, showing the asexual, male, and female weight regions.

- As. signifies the asexual weight region.
- M. signifies the male weight region.
- F. signifies the female weight region.

The line located at the point of 4 gr is the general limit between the asexual and male regions, and the line at the point of 21 gr is the general bounding line between the male and female weight regions. The lines standing at the points of 11 gr and 34 gr are the absolute limiting lines for the asexual and male regions respectively. Thus we can say that the 4 gr line shows the general limit between the asexual and male weight regions, and the 21 gr line separates the male region from the female region. The 11 gr line stands as the absolute limiting line for the asexual region, and the 34 gr line stands as the absolute limiting line for the male region.

The common regions between the general and absolute limiting lines are occupied by those corms whose sexual expression is shown either earlier or later than in those corms showing the expression in due time of growth proper to the sex. The explanation of these corms in the common regions can be attained from the point of general relation of the corm weight, or in other words, of the quantity of reserved materials and sex. The corms having a greater quantity of reserved materials produce larger vegetative shoots than the lighter corms. The size of the shoots seems to control indirectly their sexual expression.

Table XXIV.

Showing the Relation of Corm Weight and Sex in the
Common Weight Regions (in Grams).

	1918	1919	1920
No. 111	23 (male)	20 (male)	24 (male)
No. 115	24 (male)	23 (male)	—
No. 153	19 (male)	34 (male)	—
No. 470	—	9 (male)	24.5 (male)
No. 478	—	7 (male)	24.5 (male)
No. 220	12 (male)	31 (male)	—

The male corms in Table XXIV whose corm weights have already reached into the female region in 1919 or in 1920, might have been transformed into the female sex in those years as in the case of other normal corms. However, the reason why they remained in the same sex is that, as the rate of the increase in the corm weight shows, the vegetative growth of the plant was too weak to force it into the next stage of sexual expression. No. 153 (34.0 gr) might have been trans-

formed into the female sex in 1919, had it not been cultivated in the sandbed in 1918, but the apical bud formed in that year was so poor that the vegetative organs developed from it were weak and sickly. Contrary to the case shown in Table XXIV, it may happen that the vegetative organs produced by the corms are larger and more vigorous than the normal ones, then the transformation of the male corms into females would take place before they exceeded 21 gr as shown in the cases of Table XXV.

Table XXV.

Showing the Relation of Corm Weights and Sex in the Common Regions (in Grams).

	1919	1920
No. 468	10.0 (male)	18.0 (female)
No. 496	9.0 (male)	19.5 (female)
No. 509	15.0 (male)	18.0 (female)
No. 536	140 (male)	20.0 (female)

We may, therefore, summarize the data above mentioned and say that

1. the sexual expressions of the corms are correlated to their weights. Most female corms weigh above 21 gr, and most male corms weigh between 4 gr and 21 gr, while most of the asexual corms weigh under 4 gr. The relation is diagrammatically represented in Text-fig. 8. The 4 gram line is the general limiting line between the male and asexual weight regions, and the 21 gr line is the general limiting line between the male and female weight regions. The 11 gr line is the absolute limiting line for the asexual weight region, and the 34 gr line is the absolute limiting line for the male weight region. These relations are followed quite well by the corms as long as they are cultivated under normal conditions of life.

2. The corms having an undue sexual expression in relation to their weight are explained either by the reason 1) that the vegetative organs of the plants were sickly, or 2) that the vegetative organs of the plants were more vigorous and larger than normal.

6. On the Relation between the Corm Weights and the Phenomenon of Sex Transition.

It has been shown that the sex of a corm is correlated to its weight. As the weight of the corms, however, can not be expected always

to increase, it is necessary to test the mutual relation between the sex transition process and the weight changes of the corm. The study of this point will explain more clearly the nature of the phenomenon of sex transition.

Table XXVI.

Showing the Relation between the Sex Transition Process
and the Weight Change of the Corm (in Grams).

Year No.	1918	1919	1920	Year No.	1918	1919	1920
5	♀360.0	♀338.0 -22.0	♀154.0 -184.0	62	♀158.0	♀264.0 +106.0	♀32.0 -232.0
11	♀225.0	♀340.0 +115.0	♀352.0 +12.0	65	♀150.0	♀190.0 +40.0	♀118.5 -71.5
15	♀33.0	♀80.0 +47.0	♀141.0 +61.0	69	♀178.0	♀233.0 +55.0	♀233.0 0
16	♀67.0	♀156.0 +89.0	♀133.0 -23.0	79	♀177.0	♀211.0 +34.0	♀151.0 -60.0
21	♀144.0	♀201.0 +57.0	♀95.0 -106.0	81	♀145.0	♀197.0 +52.0	
27	♀159.0	♀219.0 +60.0	♀159.0 -60.0	83	♀225.0	♀225.0 0	♀233.0 8.0
33	♀155.0	♀281.0 +126.0		84	♀165.0	♀191.0 +26.0	♀147.0 -44.0
35	♀300.0	♀410.0 +110.0	♀238.0 -172.0	86	♀258.0	♀320.0 ♀62.0	
37	♀158.0	♀302.0 +144		87	♀82.0	♀140.0 +58.0	♀159.0 +19.0
39	♂32.0	♀56.0 +24.0	♀34.0 -22.0	207	♀89.0	♀133.0 +49.0	♀102.0 -36.0
44	♀49.0	♀149.0 +100.0	♀99.5 -49.5	212	♀149.0	♀213.0 +64.0	♀258.0 +45.0
46	♀57.0	♀134.0 +77.0	♀160.0 +26.0	221	♀79.0	♀135.0 +56.0	♀173.0 +38.0
52	♀148.0	♀217.0 +69.0		222	♀91.0	♀129.0 +38.0	♀82.0 -47.0
58	♀23.0	♀73.0 +50.0	♀55.5 -17.5	227	♀41.0	♀95.0 54.0	
59	♀92.0	♀166.0 +74.0	♀144.0 -22.0				

In the table given above we see that 15 corms decreased in weight during the cultivation. The causes of the decrease can be reduced to three categories, viz.: 1) partial rotting of the corm body, 2) the weak growth of the vegetative shoots, and 3) an oversupply of reserve materials for the growth of the regenerating cormlets in the axils of the protective bracts. The decrease in weight of Nos. 21, 35, 62, and 207 in 1920 was due to the first cause; while the decrease

of Nos. 16, 27, and 222 in 1920 was due to the second cause. Nos. 5, 39, 44, 59, 65, and 84 in 1920 owe their loss of weight to the second and the third reason; whereas, last, that of No. 58 and No. 79 (1920) was induced by the third cause.

But, when we examine the sex records of these corms, we find that such weight changes seem to have had little influence upon their sexual state, as they kept their female state persistently. This phenomenon may perhaps be due to the fact that the corms lay still far above the general limiting line of the female weight region and, hence, the vegetative organs produced by them were still sufficiently large to enable them to keep themselves in the same sexual state.

In the autumn of 1918, the writer prepared two beds, one for 4 gr corms and the other for the 2 gr corms. The corms in Table XXVII are the whole lot of the males found in the 4 gr bed in June of 1919. They were numbered from No. 538 to No. 602, and then transplanted carefully to a new bed. The male corms in the Table XXVIII are the entire lot of the males from the 2 gr bed found in the spring of 1920, and they were numbered from No. 613 to No. 643. Before 1919, in the 4 gr bed, and before 1920, in the 2 gr bed, there were found no sexual corms.

Table XXVII.

Showing the Relation between the Weight and the Process of Sex Transition in the Male Corms (in Grams).

Year					Year				
No.	1918	1919	1920	+	No.	1918	1919	1920	+
538	♂4.0	♂	♂17.0	13.0	557	♂4.0	♂	♂14.0	10.0
539	"	"	♂15.0	11.0	559	"	"	♀28.0	24.0
540	"	"	♂17.0	13.0	560	"	"	♀21.0	17.0
541	"	"	♀37.0	33.0	562	"	"	♂22.0	18.0
542	"	"	♂11.0	7.0	567	"	"	♀42.0	38.0
543	"	"	♂14.0	10.0	568	"	"	♂17.0	13.0
544	"	"	♂11.0	7.0	570	"	"	♀20.0	16.0
545	"	"	♂16.0	12.0	571	"	"	♂20.0	16.0
546	"	"	♂11.0	7.0	572	"	"	♀14.0	10.0
549	"	"	♂13.0	9.0	573	"	"	♂13.0	9.0
550	"	"	♂18.0	14.0	575	"	"	♂24.0	20.0
552	"	"	♀16.5	12.5	576	"	"	♂ 8.0	4.0
554	"	"	♂16.0	12.0	579	"	"	♂13.0	9.0
556	"	"	♂17.0	13.0	582	"	"	♀17.5	13.5

Year					Year				
No.	1918	1919	1920	+	No.	1918	1919	1920	+
583	♂4.0	♂	♂17.0	13.0	594	♂4.0	♂	♂12.5	8.5
584	"	"	♂18.0	14.0	595	"	"	♀24.5	20.5
585	"	"	♂11.0	7.0	596	"	"	♂18.5	14.5
587	"	"	♂14.0	10.0	597	"	"	♀18.5	14.5
588	"	"	♂10.0	6.0	598	"	"	♂20.5	16.5
589	"	"	♂11.5	7.5	599	"	"	♂14.5	10.5
590	"	"	♂18.5	14.5	600	"	"	♂11.5	7.5
591	"	"	♂ 8.0	4.0	601	"	"	♂18.5	14.5
593	"	"	♂13.5	9.5	602	"	"	♂ 7.5	3.5

Table XXVIII.

Showing the Relation between the Weight and the Process of Sex Transition in the Asexual Corms (in Grams).

Year					Year				
No.	1918	1919	1920	+	No.	1918	1919	1920	♂
613	Asexual 2.0 gr	♂	♂21.5	19.5	629	Asexual 2.0 gr	♂	♀18.0	16.0
614	"	"	„11.5	9.5	632	"	"	„23.0	21.0
616	"	"	„18.5	16.5	633	"	"	♂11.5	9.5
617	"	"	„21.5	19.5	634	"	"	„15.0	13.0
618	"	"	„17.5	15.5	635	"	"	„15.0	13.0
619	"	"	„14.5	12.5	636	"	"	♀24.5	22.5
620	"	"	„21.5	17.5	637	"	"	♂14.0	12.0
621	"	"	♀28.5	26.5	638	"	"	„16.0	14.0
622	"	"	♂10.0	8.0	639	"	"	„ 6.5	4.5
623	"	"	„11.5	9.5	640	"	"	„10.5	8.5
624	"	"	„22.5	20.5	641	"	"	„15.0	13.0
627	"	"	„ 9.5	7.5	642	"	"	„13.0	11.0
628	"	"	„ 7.5	5.5	643	"	"	♂ 9.5	7.5

In these two tables we note that the sex observed in a plant in 1919 or in 1920 is usually also its sex in the preceding year.

In Tab. XXVII, all the 46 corms had remained in the same sex for two consecutive years, but, in the third year, ten of them transformed into the female state. Among these ten females, the heaviest one weighed 42 gr (No. 567) and the lightest 14 gr (No. 572); 5 of them weighed above 21 gr, and the remaining 5 weighed less than 21 gr. The other 36 male corms remained in the same sex for three consecutive years. Among them, the heaviest corm weighed 24 gr (No. 575), and the lightest 7.5 gr (No. 602). The 34 male corms in the group,

however, weighed under 21 gr and the remaining 2 above 21 gr. In the 1920 column in Tab. XXVIII, 4 female corms and 1 monoecious one (No. 643) are found, besides 21 male corms. Three out of the 4 female corms weighed above 21 gr (Nos. 621, 632, and 636) and 17 out of 21 male corms weighed under 21 gr (Nos. 614, 616, 618, 619, 622, 623, 627, 628, 633, 634, 635, 637, 638, 639, 640, 641, and 642). The corms transformed into the female state or those which remained the same sex, showing a weight in outside the general limiting line as shown in Text-fig. 8, may be regarded as belonging to the common weight regions.

Y. On the Relation between the Sex Transition Process and the Weight of Corms in Sandbed Cultivation.

I have proved that even in sandbed cultivation the process of normal sex transition agrees well in general with that of the normal garden plot cultivation, although the process is retarded in a great measure or sometimes reversal transformation takes place. In the present chapter it is intended to interpret the phenomena of the retardation and reversion in the process of sex transition by the corm weight relation.

1. On the Weight of Sexual Corms in Sandbed Cultivation.

The corms contained in Tab. XXIX and Tab. XXX were weighed in the second year of their sandbed cultivation.

Table XXIX.

Showing the Relation of the Weights and Sex in the Female Corms cultivated in Sandbeds in 1918 (in Grams).

No.	Corm Wt.						
103	186.0	113	107.0	126	88.0	136	39.0
104	112.0	114	36.0	127	82.0	137	32.0
105	165.0	117	27.0	128	79.0	139	47.0
106	48.0	119	73.0	130	93.0	142	46.0
107	145.0	120	73.0	131	43.0	143	59.0
108	75.0	121	82.0	132	65.0	147	174.0
109	75.0	122	65.0	133	59.0	150	42.0
110	72.0	123	100.0	134	102.0	154	64.0
112	44.0	125	55.0	135	133.0	156	44.0

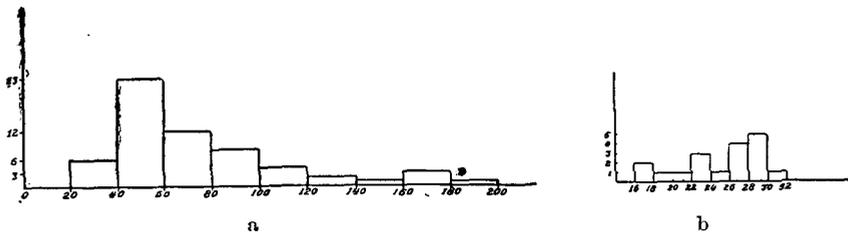
No.	Corm Wt.						
157	35.0	166	119.0	182	55.0	192	40.0
158	120.0	167	52.0	185	84.0	193	55.0
159	61.0	171	49.0	186	50.0	198	92.0
160	57.0	172	42.0	187	53.0	201	75.0
164	36.0	173	53.0	189	40.0	202	80.0
165	84.0	175	73.0	191	43.0		

Table XXX.

Showing the Relation of the Weights and Sex in the Male
Corms cultivated in Sandbed in 1918 (in Grams).

No.	Corm Wt.	No.	Corm Wt.	No.	Corm Wt.
111	23	153	19	180	16
115	27	155	24	184	17
116	27	163	22	188	28
141	29	169	28	196	27
145	29	170	31	203	21
146	29	176	27	204	22

In the above Tables XXIX and XXX, we see that the female corms weighed from 27 gr (No. 117) to 186 gr (No. 103), and the male corms from 16 gr (No. 180) to 31 gr (No. 170). The frequency distribution of the variants of different sexual states is shown in Text-fig. 9.



Text-fig. 9. Frequency polygons of the female and male corms in relation to the corm weight in sandbed cultivation.

- (a) Frequency polygon of female corms.
(b) Frequency polygon of male corms.

In this frequency distribution of the weights of the male and female corms, we find that there is a considerable number of the male variants weighing above 21 gr, and that the general limiting line between the male and female weight regions is near the point of 30 gr. Comparing this value with that of the general limiting line obtained from the corms cultivated under normal soil condition, we see that under the sandbed cultivation this value is raised about 10 gr

The sex is acquired during existence in						The sex is acquired during existence in												
forest					sandbed	garden plot	forest					sandbed	garden plot					
No.	1916	1917	1918	1919	1920	No.	1916	1917	1918	1919	1920	No.	1916	1917	1918	1919	1920	
159	♂	♂	♀61.0	♀117.0 +56.0	♀215.0 +98.0	185	♀	♀	♀84.0	♀107.0 +23.0	♀196.0 +89.0	188	♀	♀	♂28.0	♀59.0 +31.0	♀78.0 +19.0	
160	♂	♂	♀75.0	♀120.0 +45.0	♀255.0 +135.0	192	♀	♂	♀40.0	♀80.0 +40.0	♀152.0 +72.0	196	♂	♂	♂27.0	♀62.0 +35.0	♀129.0 +67.0	
163	♂	♂	♂22.0	♀43.0 +21.0	♀82.0 +39.0	198	♀	♀	♀92.0	♀147.0 +55.0	♀184.0 +37.0	201	—	♀	♀75.0	♀117.0 +42.0	♀235.0 +118.0	
165	♂	♀	♀84.0	♀153.0 +74.0	♀123.0 -35.0	203	♂	♂	♂21.0	♀39.0 +18.0	♀70.0 +31.0	204	♂	♂	♂22.0	♀43.0 +21.0	♂23.0 -15.0	
172	♂	♂	♀42.0	♀99.0 +57.0	♀204.0 +105.0													
175	♂	♀	♀73.0	♀126.0 +53.0	♀231.0 +105.0													
176	♂	♀	♂28.0	♀38.0 +10.0	♀73.0 +35.0													
180	♂	♂	♂16.0	♀33.0 +22.0	♀92.0 +54.0													
184	—	♂	♂17.0	♀50.0 +33.0	♀129.0 +79.0													

There were twenty-one female corms in the sandbed, in 1918, at the time of their transplantation into the garden plots. Nine of them had been female since 1916, and the others had progressively transformed from male corms in 1917 or in 1918. After the transplantation, these females, without any exception, remained in the same sexual state. Besides these 21 females, there were also found 10 male corms in 1918 in the same beds. Among them, 5 corms had been males since 1916. The weights of these 10 male corms were from 16 gr to 28 gr, so that most of them would have transformed into the female state before 1918, if they had been cultivated in a garden plot. After transplantation, 8 corms were transformed into the female state in the first year of the garden soil cultivation, increasing from 10 gr to 35 gr in weight, and the remaining corm (No. 155) was transformed into a female in the second year of the cultivation, increasing 20 gr in weight. Corms No. 115 and 204 were reversed once more into the asexual state in 1920. For this peculiar case of transformation the explanation will be given in the following pages.

VI. On the Relation between the Corm Weight and Reversal Transformation as well as the Retro-Transition of Sex.

In the former chapters, the writer has pointed out that the corms sometimes undergo reversal transformation during the process of

sex transition. In rare cases, the retro-transition of sex is also observed as in the case of the corm No. 115 in Table XIV. Such a reversion rarely takes place either in garden bed or in sandbed cultivation. In the former kind of cultivation, five cases (Nos. 115,¹⁾ 438, 495, 551, and 644) of reversal transformation of the male corms into the asexual state and five cases (Nos. 3, 20, 204, 215, and 654) of reversion of the female corms are observed. In sandbed cultivation, there are observed eight cases (Nos. 115, 116, 129, 174, 176, 181, 188, and 197) of reversion of the female corms into the male state. In the present chapter, the author aims to explain these cases of reversal transformation by the corm weight relation for which the data are given in the following tables.

1. On the Reversal Transformation of the Male Corms into the Asexual State.

Four cases of reversal transformation of the male corms are tabulated in Table XXXII.

Table XXXII.

Showing the Weight Relation in the Reversed Male Corms²⁾ (in Grams).

No.	1916	1917	1918	1919	1920
338	—	—	—	♂(6.0)	Asex. (6.0)
495	—	—	—	♂(9.0)	Asex. (5.0)
551	—	—	♂(4.0)	♂(4.0)	♂Asex. (2.5)
844	—	—	Asex. (2.5)	♂(?)	Asex. (8.5)

Among the corms represented in the above table, No. 438 and No. 495 belong to the O-series (No. 437 to No. 502), No. 551 belongs to the P-series (No. 538 to No. 612), and No. 644 belongs to the Q-series (No. 613 to No. 644).

Corms No. 438 and No. 495 weighed 6 gr in 1919, but when they were reversed into the asexual state in 1920, No. 438 retained the same weight, while the weight of No. 495 was decreased to 5 gr. The

1) The case of reversion of Corm No. 115 was observed twice during the experiments namely, from the female into the male state and from the male into the asexual state. Tab. XIV.

2) The case of the reversal transformation of corm No. 115 will be explained in the following pages.

other companions in the O-series in 1919 consisted of 40 males and 17 asexual corms. The sex of the remaining 8 corms could not be determined. Those male corms weighed from 4 gr to 14 gr of which two weighed 4 gr, one 5 gr, seven 6 gr, three 7 gr, six 8 gr, eight 9 gr, eight 10 gr, three 11 gr, one 12 gr, and one 14 gr. The asexual corms weighed from 3 gr to 11 gr, whereof there were one of 3 gr, four of 4 gr, two of 5 gr, three of 6 gr, four of 7 gr, one of 8 gr, and two of 11 gr. From these data we may judge that Nos. 438 and 495 probably were asexual in 1918 and weighed less than 4 gr before the reversion.

In 1920, among these 40 males, 13 male corms transformed into the female state, and 16 corms remained in the same sex. The remaining ones were lost. These 16 male corms weighed from 11 gr to 24.5 gr, whereof there were one of 11 gr, two of 12.5 gr, one of 13.5 gr, one of 14.5 gr, two of 15 gr, three of 16 gr, one of 16.5 gr, one of 20 gr, two of 20.5 gr, one of 24 gr, and one of 24.5 gr. Thus we find that these corms showed no decrease in weight, but on the contrary an increase from 5 to 16 gr. The 13 female corms mentioned above weighed from 18 gr to 56 gr, whereof there were one of 18 gr, one of 19.5 gr, one of 22 gr, one of 23 gr, two of 28.5 gr, one of 33.5 gr, one of 38 gr, one of 38.5 gr, one of 43 gr, one of 45 gr, one of 46.5 gr, and one of 56.5 gr. They increased from 8 gr to 46.6 gr. Among 17 asexual corms in 1919, 4 corms were dead and the remaining 13 were studied for their sexual state. In 1920, they consisted of 12 males and one asexual.

These 12 males weighed from 4.5 gr to 20.5 gr, whereof there were one of 4.5 gr, one of 7.5 gr, one of 8.5 gr, one of 9 gr, two of 12 gr, one of 14 gr, two of 17 gr, one of 17.5 gr, one of 18.5 gr, and one of 20.5 gr, increasing from 0.5 gr to 6 gr. The other asexual corms, however, retained the same weight that year.

These weight relations in the corms of the O-series tell us first that all the corms, both transformed and nontransformed, increased in weight, second that most of the asexual corms weighed from 4 to 7 gr, and third that the weights of the asexual corms after their transformation into the male state were from 4.5 gr to 20.5 gr. From these data we may conclude that the sexual state of the reversed male corms (No. 438 and No. 495) was asexual and that they weighed about 6 gr in 1918. However, after the reversion, these corms retained a comparatively high weight—6 gr (No. 438) and 5 gr (No. 495)—, and we

might have expected them to be in the male state instead of the reversed condition. But there are three important points to be noted: 1) their weight increase was negative, contrary to the companion corms, 2) those reversed corms were standing near the general limiting line between the asexual and the male weight regions in 1919 so that only a slight change of the corm weight is very liable to cause normal or reversal transformations, and 3) the time of reversion corresponds most likely to the first year of the male expression when the sexual state is still very unstable. Under such conditions the weak growth of the vegetative organs, which is revealed by the corm weight, must have had a considerable influence on the sex transformation in the reversed direction.

No. 551 remained male in 1918 (4 gr in weight) and in 1919, but in the next year (1920) it reversed into the asexual state, weighing 2.5 gr. In 1920, the companion corms in the P-series consisted of 10 females and 34 males, the remaining 16 corms died during cultivation. The companion male corms, 34 in number, weighed from 7.5 gr to 24.5 gr, whereof there were one of 7.5 gr, two of 8 gr, one of 10 gr, five of 11 gr, one of 11.5 gr, one of 12.5 gr, one of 13 gr, one of 13.5 gr, five of 14 gr, one of 14.5 gr, one of 15 gr, three of 17 gr, one of 17.5 gr, three of 18 gr, two of 18.5 gr, two of 20 gr, one of 22 gr, one of 23.5 gr, and one of 24.5 gr. They increased from 3.5 gr to 20.5 gr during the previous two years, and the average weight (14.9 gr) of the 34 male corms in 1920 was increased about 3.7 times compared with the weight at starting. The female corms, 10 in number, weighed from 14.5 gr to 42 gr, of which there were one of 14.5 gr, one of 16 gr, one of 16.5 gr, one of 17.5 gr, one of 18.5 gr, one of 20 gr, one of 21 gr, one of 28 gr, one of 37 gr, and one of 42 gr. They increased from 10.5 gr to 38 gr, and the average weight (23.1 gr) of these females in 1920 was increased about 5.8 times compared with the starting weight (4gr) in 1918.

This shows that the vegetative growth of the female corms had been more energetic than that of the male companions. Thus, in spite of the weight increase of all corms in the P-series, corm No. 551 was the sole exceptional case in which the weight showed a decrease of 1.5 gr and a change to the asexual state in 1920.

Corm No. 644 weighed 2.5 gr in 1918 like the companion corms in the Q-series. In 1920, the sexual state of the Q-series consisted of 21 male corms, 4 female corms, one monoecious corm (No.

644), and five corms whose sexual state was unknown. The 21 male corms weighed from 6.5 gr to 22 gr, whereof there were one of 6.5 gr, one of 7 gr, one of 9.5 gr, one of 10 gr, one of 10.5 gr, three of 11.5 gr, one of 14 gr, one of 14.5 gr, three of 15 gr, one of 16 gr, one of 17 gr, one of 18.5 gr, one of 19 gr, three of 21.5 gr, and one of 22 gr. They increased from 4.0 gr to 19.5 gr during two years cultivation, and their average weight (14.7 gr), in 1920, is about 5.9 times their starting weight (2.5 gr) in 1918. The four female corms weighed from 18 gr to 24 gr, whereof there were one of 18 gr, one of 23 gr, one of 24 gr, and one of 28.5 gr. The mean weight (23.4 gr) is about 9.4 times the weight in 1918, showing an increase from 15.5 gr to 26 gr for two years' cultivation. Thus, female corms and male corms belonging to the Q-series had increased their weight 5.9 times or more in 1920, except No. 644 which would have grown to about 15 gr and expressed the male state after two years' cultivation. Probably this decrease in weight is due to the weak growth of the vegetative organs in 1919. We may summarize the above statements as follows:

1) From the weight study of the reversed male corms, we find that the reversion takes place almost always together with a decrease in weight.

2) And it is also very important to notice that the reversion is very frequent in the corms with weights near the general limiting line, where the corms are susceptible to the slightest change of weight in determining their sexual state.

3) Sometimes reversal transformation takes place in the corms showing the same weight for years through want of stimulation for the advancement of the process.

2. On the Cases of Reversal Transformation of the Female Corms into the Male State.

Twelve cases of reversal transformation of the female corms are tabulated in Table XXXIII.

Table XXXIII.

Showing the Weight Relation in the Reversed Female Corms (in Grams).

No.	1916	1917	1918	1919	1920
3	—	♀	♀(102.7)	♂(61.0)	—
20	♂	♀	♂ (34.0)	—	—

215	♂	♀	♂ (37.0)	—	—
645	—	—	—	♀—	♂ (8.5)
116	♂	♀	♂ (27.0)	—	—
129	♀	♀	♂ (54.0)	—	—
174	—	—	♂ (30.0)	—	—
176	♂	♀	♂ (28.0)	—	—
181	♂	♀	♂ (33.0)	—	—
188	♀	♀	♂ (28.0)	—	—
197	♂	♀	♂ (31.0)	—	—
204	♂	♂	♂ (22.0)	♀(43.0)	♂(28.0)

Corms No. 3, 20, and 215 belong to the A-series which have been cultivated since 1917 in garden soil plots (from No. 1 to No. 102 and from No. 205 to No. 291). Nos. 116, 129, 174, 176, 181, 188, 197, and 204 belong to the B-series which have been cultivated since 1917 in sandbeds (from No. 103 to No. 204).

In 1918, there were found 108 female corms in the A-series. Among them, 54 corms had been male corms in 1916, and their weights in that year were from 39 gr to 225 gr, the mean being about 132 gr. Judging from these data, the probable cause of the reversion in the corms No. 20 and No. 215 is that they were growing as well as the other corms until 1917, but decreased in weight during the first year of their female expression on account of the weak growth of the vegetative organs, and were reversed into the male state.

Corm No. 645 is one of the very interesting examples. This plant was one of the rarest of abnormal specimens, bearing one female scape and only one foliage leaf and looking very weak in our garden plot in 1919. In the next year, this plant presented itself as a male plant weighing about 8.5 gr. This case of reversion must be due to this curious shortage in the number of the foliage leaves, whereby the corm weight was reduced to 8.5 gr.

On the other hand, eight cases of reversion were secured in the sandbed cultivation. There were 59 female companion corms in this series in 1918. Among them some ones which had been male in 1916 weigh about 53.7 gr on the average and the others which had been females for the consecutive three years weigh, however, 87.3 gr on the average. From these data we can conclude that those reversed corms ought to have been at least near 53.7 gr in 1918. But they seem to have been affected very much by the sterile condition of the soil, because their weight was decreased about 20 gr or more so that they were reversed into the male state in the first year of the female

expression. Corm No. 188 was female in 1916 and ought also to have been at least near 87.3 gr in 1918. But the corm probably lost 59.3 gr in the vegetative period in 1918 and was obliged to reverse into the male state. No. 204 increased in weight very slowly in sandbed life. After the transplantation into the garden plot, this corm readily recovered its vegetative functions so that it was transformed into the female state. But in the next year (1920) the weight was suddenly decreased to 28 gr by some injuries and it reversed into the male state.

Again, we notice that Nos. 20, 116, 174, 176, 181, 188, 197, and 204 underwent the reversal transformation with a corm weight of from 27 gr to 34 gr, although these weights are above the general limiting line (21.0 gr) of the female region under normal conditions of life. The reversion in this case may be interpreted as showing that the assimilation products prepared by them were insufficient to sustain the female state because of the diminution in the vegetative organs or on account of the extreme sterile condition of the soil.

The weight of corms No. 3 (61 gr), 215 (37 gr), and 129 (54 gr), however, lay above the absolute limiting line of the male region, and it would seem improbable for them to reverse. Corm No. 3 weighed 102.5 gr in 1918, but it decreased in weight to 61.0 gr (about 59.5%) in the next year because of a severe wound inflicted by a crow at the apical portion of the bud so that the vegetative organs scarcely developed during the subsequent vegetative season. This was the direct cause of the reversal transformation. No. 129 was also one of the corms injured in 1919. In the spring of that year this corm unfortunately happened to be dug out by a dog, when the foliage leaves were just developing their blades, and, moreover, it was left exposed for a day so that the roots and foliage leaves were severely injured. By this accident the after-growth was very poor, causing the corm to reverse. Thus we come to know by these facts that even female corms of a high weight are also able to undergo sex reversion through weakened growth of the vegetative organs or by some serious disturbances of the function of the organs. No. 215 is also one of those special corms in which the reversal transformation appeared as the outcome of special injuries. This corm was one of those which were brought into the author's laboratory for the examination of the corm body just a month before planting in the plot. Unfortunately, the corm began to sprout and to elongate the apical buds in the room temperature,

and when they were planted in the plot, corm No. 215 suffered pretty severe injuries at the root tips.

3. On the Relation of Corm Weight and Retro-Transition of Sex.

The process of retro-transition of sex is characterised by a reversal transformation which takes place twice in the sexual life of the corm, that is, from the female to the male and from the male to the asexual. This kind of process is represented by corm No. 115 as follows:—

No.	1916	1917	1918	1919	1920
115	♀	♂	♂(27.0)	♂(20.0)	Ase. (14.0)

In this record of retro-transition of sex, we see a fair accordance of the weight decrease with the reversal transformation. This corm was cultivated in the sandbed in 1917 (in the first year of the reversal transformation) and also in 1918, and it thus met with a severe check of the vegetative growth during the period. In 1919, the corm still retained the male state even after the transplantation to garden soil on account of its weakened vegetative growth as an after-effect of the sandbed cultivation (decreasing 7 gr in weight). In the following year, 1920, this corm happened to be injured very much and decreased further in weight (6 gr); finally, it reversed to the asexual state for the second time.

Now, turning our attention to the weight of this corm in 1920, we see once more the fact that the weight of the corm is a little higher than the absolute limiting line of the asexual weight region as we saw in the case of the No. 3, No. 215, and No. 129. In this case of abnormal reversion, we can point out, as in other cases described above, the same effect of severe injuries inflicted on the plant body during the growing season.

4. Summary.

- 1) Sex reversion is most frequent when the corm weight stands near the limiting line.
- 2) Sex reversion is generally accompanied by a decrease of corm weight.
- 3) Therefore, if the decrease of corm weight continues for years, the female corms may be reversed back to the asexual state, *i. e.* suffer retro-transition of sex.
- 4) Sex reversion is observed even in the male and female corms

weighing more than their respective absolute limiting lines indicate.

5) In these abnormal cases of reversal transformation, we always see that, due to various causes, the plants have undergone some severe injury to their vegetative organs and decreased very much in weight.

6) These cases of normal reversal transformation shed some light on the question of sex control even in the corms of high weight.

VII. On the Experimental Control of Sex in

Arisaema japonica Bl.

In the former chapters the writer has been concerned with the phenomena of sex transition and retro-transition of sex, which are correlated with the increase or decrease of corm weight; and also it has been found that, even in the heavy corms, sex is transformed reversely when they are severely injured in their vegetative organs and thereby decrease their corm weight very much.

Experiments were devised to prove that 1) artificial change of the weight of a corm can control its sexual state and 2) if the corm weight is recovered, it will return to the former sexual state and thereafter follow the general process of sex transition.

For these purposes we can easily devise several methods to decrease the corm weight; namely, 1) corm cutting, 2) leaf blade cutting, 3) leaf cutting, and 4) dark room cultivation.

On the other hand, however, to increase the corm weight by an artificial method is not so easy a matter. At first, I have vainly sacrificed many valuable corms trying to graft small corms upon large sized ones. This kind of manipulation seemed very difficult in this plant, and I had to await the natural increase of weight for this purpose.

A. Sex Control Through Corm Cutting.

1. Method.

By this method, the decrease of corm weight is directly attained. A corm body was cut down to a certain limit with special care under due precaution against injury of the basal part of the apical bud and then planted in an experimental plot. In these experiments male as well as female corms were used.

2. On the Sex Control of Male Corms.

Table XXXIV.

Showing the Results of Corm Cutting in the Male Corms
(in Grams).

Year No.	1916	1917	1918	1919		1920
				Reduced to	Recovered to	
20	♂	♀	♂34.5	9.0 (-25.5)	♂16.0 (+7.0)	♀35.0 (+19.0)
174	—	♀	♂30.0	14.0 (-16.0)	♂24.0 (+10.0)	♀27.0 (+3.0)
181	♂	♀	♂33.0	12.0 (-21.0)	♂13.0 (+1.0)	♀34.0 (+21.0)
197	♂	♀	♂31.0	13.0 (-18.0)	♂15.0 (+2.0)	♀36.0 (+21.0)
215	♂	♀	♂37.0	21.0 (-16.0)	♂28.0 (+7.0)	♂27.0 (-1.0)

The corms in the above table had been all females in 1917, but they were reversed into males in the year before manipulation (1918). The weight of these corms, in 1918, was comparatively high (from 30 gr to 37 gr), so that it could be presumed that they possessed a tendency to change into the female state in the next year.

These corms were cut down from 9 to 21 gr in the spring of 1919 and their sexual states were examined. The results met the expectation very well as their female expression was interrupted, though they had recovered from 13 gr to 28 gr in weight during the vegetative period.

After a year's nursing in garden soil, however, they (Nos. 20, 174, 181, and 197) came back again into the former female sex, recovering almost the weight they had in 1918.

3. On the Sex Control of Female Corms.

Table XXXV.

Showing the Results of Corm Cutting in the Female Corms
(in Grams).

No.	1916	1917	1918	1919		1920	1921	
				Reduced to	Recovered to		Reduced to	Recovered to
114	♂	♀	♀36.0	15.0 (-21.0)	♂18.0 (+3.0)	Asex. 13.5 (-4.5)	—	-9.5 (-4.0)
125	♀	♀	♀55.0	25.0 (-30.0)	♂19.0 (-6.0)	♀40.0 (+21.0)	—	-23.0 (-17.0)
133	♀	♀	♀59.0	25.0 (-34.0)	♂20.0 (-5.0)	♀26.0 (+6.0)	—	—
139	—	♀	♀47.0	19.0 (-28.0)	♀39.0 (+20.0)	♀31.0 (-8.0)	11.0 (-20.0)	—

No.	1916	1917	1918	1919		1920	1921	
				Reduced to	Recovered to		Reduced to	Recovered to
150	♂	♀	♀42.0	20.0 (-22.0)	♀50.0 (+30.0)	♀30.0 (-20.0)	9.0 (-21.0)	♂14.0 (+5.0)
167	♂	♀	♀32.0	23.0 (-9.0)	♀63.0 (+40.0)	♂38.0 (-25.0)	7.0 (-31.0)	—
171	♂	♀	♀49.0	16.0 (-33.0)	♂37.0 (+21.0)	—	—	—
173	♀	♀	♀53.0	19.0 (-34.0)	♂16.0 (-3.0)	♂23.0 (+7.0)	—	♂23.0 —
186	♀	♀	♀50.0	24.0 (-26.0)	♀36.0 (+12.0)	♀29.0 (-7.0)	10.0 (-19.0)	♂11.0 (+1.0)
187	♂	♀	♀53.0	23.0 (-30.0)	♀55.0 (+32.0)	♀37.0 (-18.0)	12.0 (-25.0)	♂20.0 (+8.0)
189	♀	♀	♀40.0	22.0 (-18.0)	♀35.0 (+13.0)	-27.0 (-8.0)	7.0 (-20.0)	—
191	♀	♀	♀43.0	22.0 (-21.0)	♀50.0 (+28.0)	♀40.0 (-10.0)	13.0 (-27.0)	♂15.0 (+2.0)
193	♀	♀	♀55.0	28.0 (-27.0)	Asex. (20.0) (-8.0)	—	—	—

Among the corms in the above table, the Nos. 125, 133, 173, 186, 189, 191, and 193 had been of the female sex consecutively for three years since 1916, weighing in 1918 from 40 to 59 gr; and corms No. 114, 150, 167, and 171 were in the female state for two years since 1917, weighing in the last year from 36 gr to 53 gr. Therefore, the female state of these corms before the year of the manipulation may be regarded as quite stable.

The vegetative growth of the manipulated corms, in 1919, was not uniform. Some of them looked pretty sound, while others looked very morbid and poor (No. 193 for example) and entered into the resting stage early in June before the formation of the young spadix was finished. Corms No. 125, 133, 173, and 193 showed a decrease from 3 gr to 8 gr. The Nos. 114, 139, 150, 167, 171, 186, 187, 189, and 191 recovered from 3 gr to 40 gr as the result of a comparatively healthy growth after manipulation.

As a consequence of the experiment, the female corms No. 114, 125, 133, 171, and 173 were reversed into males in 1919, remaining below the general weight limit of the female region, except corm No. 171. The female corms No. 139, 150, 167, 186, 187, 189, and 191 remained persistently in the same sex, showing a greater weight than the absolute limit of the male region indicated.

In the fall of 1920, we found in the plot of the reversed male corms that corms No. 125 and 133 had returned into the female state, showing an increase of 21 gr and 6 gr respectively. Corm No. 173 was

sexually unchanged, while No. 114 was reversed once more into the asexual state. Similarly, in the plot of the female corms, we find that No. 167 was reversed into the male state, whereas the Nos. 139, 150, 186, 187, and 191 showed still the same sex.

For the purpose of removing the female expression from these latter five female corms, the author applied to them the second manipulation in the spring of 1921, reducing their weight from 9 gr to 13 gr. The result was a complete success, and every corm was reversed into the male sex.

Thus all the female corms in 1918 were changed into males or even into the asexual state through the male by the artificial reduction of the corm weight, so that it appears clear that the corm weight bears some relation to the determination of the sex. Now, we come to the point where we have to answer the following interesting questions, that is: What is the relation between the corm weight and the sexual expression of the plant, and what is the true determinant of the sex of the plant?

In the above chapters, our attention has often been attracted to the fact that the sex of a corm is not necessarily correlated to its weight. For example, reversal transformation, so far as this can be observed even in a heavy corm standing higher than the absolute limit, occurs only when a regressive vegetative condition prevails, and we have never met with a case yet in which the reversion takes place together with an increase in corm weight. With regard to these cases of abnormal reversion, the author has noticed that the reversion is always due to some kind of serious injury to the vegetative organs, or otherwise, to a weakened or morbid condition of the plant.

In this experiment, we have also four cases of abnormal reversion (Nos. 114, 167, 171, and 173). Among them, we see in corm No. 114 that the process of the retro-transition of sex is experimentally proved by the artificial control of the corm weight. In its process of sexual retro-transition, this corm was in the male state in 1919, and in the next year (1920) it was reversed again into the asexual state, decreasing 4.5 gr in weight. As to the cause of the reversion, the author attributes great importance to the fact that the corm had formed an extremely incomplete apical bud in 1919 as a result of the weakened growth of the vegetative organs caused by the experimental manipulation of the corm in the same year, so that, as a consequence, the vegetative organs formed in the year of reversion (1920) were very

weak and morbid. Thus we can easily see that the decrease in the corm weight and the reversion of the sexual state are both directly related to the state of the vegetative organs. On the other hand, we can also see that this state of the vegetative organs is primarily related to the quantity of the formative assimilation products, or, in other words, to the fresh assimilation products before they are stored. The author thinks that it may not be irrational to assume that the quantity of the formative assimilation products is the determining factor of the sex, and that the weight of the corm is nothing more than a mere index of the sexual expression of the corm.

Now, it is very interesting to recall the fact that the sexual state of a corm generally corresponds with the governing weight region of the said sex, that the corm weight is the index of the sexual expression of the corm, and that by the experimental weight decrease of the corm the sex of the plant can be controlled. The author thinks that these data serve also as a positive affirmation of the assumption that the quantity of the formative assimilation products serves as determiner of the sex in the plant.

The author wishes to draw attention to the fact that there exists a clear relation between the size of the assimilation organs and the size of the corm, namely, the large corm produces large foliage leaves, and the small corm produces small sized foliage leaves. And it must also be recognized that, as the size of the foliage leaves is proportional to the quantity of the reserved assimilation products, so the size of the corm must be proportional to the quantity of the formative assimilation products. Therefore, so far as the relation of the sex and the corm weight is concerned, we can say without doubt, that the sexual expression of the plant corresponds to the quantity of the formative assimilation products or, in other words, that the quantity of the formative assimilation products determines the sexual state of the plant. It also follows from the above statements that the weight of the corms is the index of their sexual expression. Thus, the moment of sex determination may be thought of to occur, when a certain quantity of the assimilation products is accumulated in the tissues of the embryonic apical bud. The sex of the new scape itself is determined according to the quantity of the materials present. However, without a certain minimum quantity of assimilation products, the corm cannot express the sexual state and remains asexual. The author wishes to stress the importance of

the difference between the formative assimilation products and the reserved assimilation products. In the normal case of sex transition, the quantity of the formative assimilation products is proportional to the size of the corms as well as to that of the foliage leaves. However, this relation may not always hold when the plant happens to be injured or when the vegetative organs become weakened and morbid. In this case, the abnormal reversion usually takes place. For example, the assimilation organs of corm No. 114 were, in 1920, very weak and morbid, and it may be assumed that the quantity of the assimilation products was deficient for the corm to give sufficient stimulation for the male expression; therefore, it reversed into the asexual state. The other cases of abnormal reversion seen in the above table (Nos. 167 and 173) may also be interpreted in the same way. No. 167 was reversed into the male state by the weak vegetative growth of the assimilation organs in 1920, corm No. 173 remained in the same sex with the weight of 23 gr, because the vegetative growth of the assimilation organs was not sufficiently energetic and the formative assimilation products were insufficient to transform the corm from the male state into the female sex.

4. Summary.

- 1) The sex of the corm can successfully be controlled by removing certain parts through cutting.
- 2) No corm is fixed to one sexual state.
- 3) The author believes that the sex in this plant is determined by the quantity of the formative assimilation products, or, in other words, by the assimilation products in the fresh form before they are stored in the reserve organ.
- 4) The corm weight can be regarded as the index of the sexual state of the corm.

B. Sex Control Through Cutting of the Leaf Blades.

1. Method.

The leaf blade of *Arisaema japonica* is divided into three leaflets. The terminal leaflet is small, entire, and single, but the lateral leaflets are large, pinnately divided or parted. The cutting of the leaf blades is undertaken in two ways, namely, a strong grade of cutting (A) and a light grade of cutting (B). Whereas the latter grade of cutting is

simply obtained by removing the entire leaf blade of the lower foliage leaf, the former is attained by extending the cutting to the lateral leaflets of the upper foliage leaf, leaving only its terminal leaflet behind. These manipulations are applied as soon as the blade emerges out of the protecting bracts. After the manipulation the plant grows pretty well, so that the apical bud of the corm is satisfactorily formed in every case.

2. On the Results of the Manipulation.

Table XXXVI.

Showing the Result of the Removal of the Leaf Blades through Cutting in the Female Plant.

No.	1916	1917	1918	1919		1920	
				Grade	Recov'd to	Grade	Recov'd to
10	♀	♀	♀117.0	A	♂74.0 (-43.0)	—	♂71.0 (-3.0)
17	♀	♀	♀129.0	B	♀82.0 (-47.0)	—	—
18	♀	♀	♀129.0	A	♀74.0 (-55.0)	A	♀51.0 (-23.0)
19	♀	♀	♀121.0	B	♀118.0 (-3.0)	A	♀81.0 (-37.0)
26	♀	♀	♀129.0	B	♀73.0 (-56.0)	A	♀40.0 (-33.0)
47	♀	♀	♀137.0	A	♀81.0 (-56.0)	A	♀48.0 (-33.0)
56	♂	♀	♀139.0	B	♀93.0 (-46.0)	A	♀57.0 (-36.0)
75	—	♀	♀113.0	B	♀66.0 (-47.0)	A	♀56.0 (-10.0)
89	♀	♀	♀136.0	A	♂74.0 (-62.0)	—	♀105.0 (+31.0)
92	♂	♀	♀192.0	A	♂60.0 (-132.0)	—	♀70.0 (+10.0)
94	—	♀	♀103.0	A	♀70.0 (-33.0)	A	♀50.0 (-20.0)
96	♀	♀	♀109.0	B	♀105.0 (-4.0)	A	♂48.0 (-57.0)
97	♀	♀	♀127.0	A	♀74.0 (-53.0)	A	♂30.5 (-43.5)
104	♀	♀	♀112.0	B	♀73.0 (-39.0)	A	♂32.0 (-41.0)
107	♀	♀	♀145.0	B	♀166.0 (+21.0)	—	♀178.0 (+12.0)
123	♀	♀	♀100.0	A	♀54.0 (-46.0)	A	♂35.0 (-19.0)
134	♀	♀	♀102.0	A	♂52.0 (-50.0)	—	—

135	♀	♀	♀133.0	B	♀174.0 (+41.0)	A	♀150.0 (-24.0)
158	♀	♀	♀120.0	A	♂64.0 (-56.0)	—	♀117.0 (+53.0)
166	♂	♀	♀119.0	A	♀104.0 (-15.0)	A	♀95.0 (-9.0)
209	♂	♀	♀105.0	A	♂49.0 (-56.0)	—	♀60.0 (+11.0)
213	♂	♀	♀133.0	B	♀95.0 (-38.0)	A	♂40.0 (-55.0)
225	♂	♀	♀129.0	B	♀172.0 (+43.0)	—	♀143.0 (-29.0)
226	♂	♀	♀122.0	B	♀83.0 (-39.0)	A	♀61.0 (-22.0)

Twenty four corms were experimented upon in the spring of 1919. Corms No. 107, 135, and 225 showed good resistance and an increase from 21 gr to 43 gr, retaining the female state. But Nos. 10, 17, 18, 19, 26, 47, 56, 75, 89, 92, 94, 96, 97, 104, 123, 134, 158, 166, 209, 213, and 226 showed a loss in weight from 3 gr to 132 gr, weighing from 49 gr (No. 209) to 118 gr (No. 19). Among these decreased corms, 6 (Nos. 10, 89, 92, 134, 158, and 209) were reversed into the male state. They weighed from 49 gr to 74 gr, showing a considerable decrease in weight. These reversed corms belong to the group which received the strong grade of cutting, so that the cause of reversion must certainly be ascribed to this strong grade of disturbance.

It is very interesting to notice that this state of reversion corresponds very well with those cases of reversed plants whose vegetative growth was weakened by the cutting of the corm or by sandbed cultivation. The cultivation of all these corms was continued for further observation. The reversed male corms were untouched in the same plot the next year, but with the female corms further cutting was tried.

In 1920, among six reversed corms, No. 10 (decrease 3 gr) remained in the same state, while No. 89 (increase 31 gr), No. 92 (increase 10 gr), No. 158 (increase 53 gr), and No. 209 (increase 11 gr) returned to the former female state. Among eighteen female corms, No. 96 (decrease 57 gr), No. 97 (decrease 43.5 gr), No. 104 (decrease 41 gr), No. 123 (decrease 19 gr), and No. 213 (decrease 55 gr) reversed into the male state on account of the continuous weak condition of the vegetative growth, while No. 18 (decrease 23 gr), No. 19 (decrease 37 gr), No. 26 (decrease 33 gr), No. 47 (decrease 33 gr), No. 56 (decrease 36 gr), No. 75 (decrease 10 gr), No. 94 (decrease 20 gr), No. 135 (decrease 24 gr),

No. 166 (decrease 9 gr), No. 225 (decrease 29 gr), and No. 226 (decrease 22 gr) were still adhering to the female state.

The results of this experiment show that the reversed male corms soon recover their former sex, if they are permitted to grow in the normal way with the vegetative organs unmolested. After all, the cutting of the leaf blades seems to have a rather moderate influence upon the reversion of the sex.

C. Sex Control Through Cultivation in a Dark Room.

1. Method.

For the purpose of weight reduction this method may surpass any of the other manipulations, as we can attain the object without wounding the corm. The plants were potted when the entire leaf blades were developed and then placed under an enclosed plant bench in a green house (June 27, 1920), where they were left without any care except occasional watering, until they entered into a dormant state. In this dark room their leaves turned pale yellow, and the petioles became etiolated and slender.

2. On the Results of the Dark Room Cultivation.

Table XXXVII.

Showing the Results of the Dark Room Cultivation in 1920
(in Grams) I.

No.	1919	1920	No.	1919	1920
503	♀35.0	♂26.0 -9.0	526	♀19.0	*8.0 -11.0
505	♀23.0	*13.0 -10.0	529	♀11.0	Asex. 8.5 -2.5
506	♀24.0	*11.0 -13.0	532	♀17.0	*13.0 -4.0
514	♀16.0	*15.5 -0.5	533	♀26.0	♂19.0 -7.0

Table XXXVIII.

Showing the Results of the Dark Room Cultivation in 1920
(in Grams) II.

No.	1917	1918	1919	1920
558	Asex.	♂4.0	♀	*8.0
563	Asex.	♂4.0	♀	*4.5

564	Asex.	♂ .0	♀	Asex. 8.0
565	Asex.	♂ 4.0	♀	Asex. 6.5
569	Asex.	♂ 4.0	♀	*12.0
574	Asex.	♂ 4.0	♀	*10.5
577	Asex.	♂ 4.0	♀	Asex. 6.5

This treatment seems to have been too extreme for the vegetative life of the plants. The corms marked * displayed no shoots the next year and died. The other 4 corms, however, displayed leaf shoots, but without any scapes, while No. 503 (decrease 9 gr) and No. 533 (decrease 7 gr) reversed into the male state.

We have already stated that the *Anlage* of the young apical bud at the axil of the lower leaf is, at the beginning of July, still in a rudimentary stage of differentiation, consisting of a few slightly differentiated bracts only. The differentiation of the apical bud begins in June through the formation of the incipient bracteal leaves. In July, the incipient foliage leaves appear from the beginning to the middle of the month whereupon, in late July or the beginning of August, the papillae of the premodial flowers are formed, which reach their full differentiation as male or female flowers from the middle of August to the beginning of September. Therefore, we know from the cases of the reversal transformations in corms Nos. 503 and 533 that the formation process of the apical buds for the next year proceeded regardless of the presence or absence of the assimilation organs thanks to the scant supply of the formative assimilation products inverted from the reserved materials. This interesting fact led me to proceed to the next step of the experiment.

3. Summary.

- 1) The formation process of the apical buds proceeds regardless of the presence or absence of the assimilation organs.
- 2) However, most of the female corms cultivated in such an extreme condition as that described above failed, except in the case of the two reversed corms, to form complete apical buds.
- 3) These results may be explained by the scanty supply, from the shoots, of the formative assimilation products.

D. Sex Control Through Leaf Cutting.

In these experiments the aim was to make a critical study of the

question whether the corm weight means more than a mere index of the sex of the plant or not.

1. Method.

For this purpose, seven healthy female corms were selected in the experimental plot and the vegetative organs above the ground were entirely cut away on the 1st of July, 1920.

2. On the Results of the Manipulation.

After the manipulation no special organ development was seen in the corms except the apical bud differentiation for the next year.

Table XXXIX.

Showing the Result of the Leaf Cutting Manipulation in 1920
(in Grams).

Year			Year		
No.	1919	1920	No.	1919	1920
429	♀41.0	♂27.5 (-13.5)	433	♀36.0	Asex. 20.5 (-15.5)
430	♀65.0	♂44.5 (-20.5)	434	♀55.0	♂41.0 (-14.0)
431	♀46.0	Asex. 41.0 (-5.0)	436	♀74.0	♂55.5 (-18.5)
432	♀43.0	♂33.5 (-9.5)			

As no conspicuous differentiation of the apical bud takes place in the corm before July, the new apical bud, developed in the manipulated corm, must have owed its resources for the organ formation to the assimilation products accumulated before July 1st and also to the reserved materials formed in the previous years and left unused in the corm.

In the above table, the five female corms transformed reversely into the male state with the weight mostly above the absolute limiting line for the male weight region (from 27.5 gr to 55.5 gr), while the remaining two failed to form the inflorescence. In this case, it is very plain that if the quantity of the reserved materials plays a direct rôle on the determination of the sex, the corm should take, as a matter of course, the female expression instead of the male expression. But the reason why the sexual reversion took place in such heavy corms must doubtless be due to the absence of the foliage leaves. The presence of the foliage leaves, in this case, means an abundant

supply of formative assimilation products. Therefore, the principal rôle played by the reserved materials on the sex determination lies indirectly in the formation of the foliage leaves which are directly concerned in its determination by the production of the formative assimilation products, as we have repeatedly stated.

Corms No. 431 and No. 433 underwent a reversal transformation from the female directly to the asexual state, omitting the intermediate male state. We have found nine similar cases of the reversal sex transformation in Tab. XXXVII and Tab. XXXVIII for which the author's view has already been given.

3. Summary.

1) Most of the female corms whose leaves were cut on the 1st of July were able to form the complete apical buds for the next year. All of these female corms changed into males.

2) The cause of the reversion may be due to the absence of the assimilation organs and the poor supply of the formative assimilation products at the period of the bud differentiation.

3) Therefore, we can say that the sex is determined directly by the quantity of the formative assimilation products, and the weight of a corm means no more than a mere index of its sex.

VIII. General Statement of the Results of the Observations and Experiments on Sex Determination in *Arisaema japonica* Bl.

It has been the writer's aim in the present investigation to elucidate the phenomenon of sex transition and reversal transformation of sex in *Arisaema japonica*. The author thinks that his view on the determination of sex as being directly related to the quantity of the formative assimilation products is the only permissible interpretation for these phenomena. The cytological and Mendelian interpretation of the sex determination that prevails with regard to the animal kingdom, is quite inapplicable for the explanation of these phenomena in *Arisaema japonica*. Because all the corms, without a single exception, have not their own fixed sexuality, and they are invariably transformed in their sex according to the process of sex transition.

Neither can we apply the inhibition theory of sex determination, in which it is presumed that the dominant sex is inhibiting the other

sex in one and the same prothallium or inflorescence, because we have found some specimens of the monoecious spadix during our experiments, and also, even though that theory be taken as granted, the primary cause of excluding the influence of the dominant sex for the new one has been proved already to be due to the quantity of the formative assimilation products. Nor can we assume the existence of any special chemical substances for the determination of the male or female sex, because the sex control of one and the same plant is easily attained by various methods. The author's view of the phenomenon of sex transition in *Arisaema japonica* may be briefly stated as follows:—

The size of the assimilation organs of an asexual plant whose corm weight is under 4 gr, is very small, and the period of its vegetative life is also short, so that the quantity of the formative assimilation products formed during the season falls too short to help the corm in the formation of the sexual scape for the next year. But when the corm grows from 4 gr to 21 gr the assimilation organs produced by it are sufficiently strong to supply the necessary quantity of the formative assimilation products for the male expression. And if the corm weighs above 21 gr, the vegetative shoot produced by it is sufficiently vigorous to allow it the female expression. As the corm grows larger, the quantity of the formative assimilation products becomes greater so that the sexual state becomes more stable. Sometimes it occurs that the vegetative shoot does not grow large enough to correspond to the corm weight. In such a case, the male expression in the corms above 21 gr or the asexual expression in those above 4 gr is the rule. Or, there may also happen the case in which the condition favours the growth of vegetative shoots over their size. In such a case, we find the female expression even in a corm weighing under 21 gr. This is the explanation of the process of normal transition.

If the growth of the vegetative shoot becomes weakened or impaired and the corm weight is decreased year after year, then, the sexual expression of the corm is reversely transformed from female to male and from male to asexual. This is the explanation of the process of retro-transition of sex.

In the sandbed corms, we found the process of sex transition greatly retarded and the rate of reversal transformation greatly increased. These abnormal phenomena of sex transition can be understood by the poor growth of the vegetative organs, causing an insufficient production of formative assimilation products for the promotion of the

process, or insufficiency to support the former sex. We may regard the experimental control of the sexual state by various methods (by corm cutting, leaf blade cutting, dark room cultivation, and leaf cutting) as the direct proof of this explanation.

We may summarize the above statements and conclusions with regard to the sexual expressions, corm weight, and the process of sex transition as follows :—

Summary.

1) For the female expression the greatest quantity of the formative assimilation products is required. For the male expression, a medium quantity of these products is needed. And in the asexual state, the sexual expression is not attained on account of the insufficient supply of the formative assimilation products.

2) The weight of the corm has no direct influence upon the sex determination; it serves only as an index of the sexual expression of the corm. The greater the weight of the corm the larger the size of the assimilation organs produced; and, as a consequence, the quantity of the formative assimilation products will be greater.

3) The process of the transition and retro-transition of sex together with the reversal transformations may be explained by the quantity of the assimilation products present when the formation of the new apical bud for the next year is taking place.

Discussion.

A great deal has been written on the nature of sex and on the cause of sex determination in the plant world. Some of the authors base their view point on the findings of modern genetics, some others on the results of cytological and phylogenetical studies, while still others hope to get near the truth through physiological researches based on the experimental control of the sex.

In his investigation on the gynodioecious plants (*Satureia hortensis* and some others), C. Correns (1908a, p. 686) remarked that the seeds of hermaphrodite individuals produce dominantly hermaphrodite plants and those from the female plants produce dominantly female individuals. His experiments on *Plantago lanceolata* show the interesting influence of the pollen, so that the sex ratio of the progenies displays an inclination either to male or female according to the predominance of either male or female flowers in the pollen producing plant.

In 1907, C. Correns in his reputed experiments on *Bryonia alba* and *Bryonia dioica* reported the following results, namely, 1) 100 female generative cells of *Bryonia dioica* plus 100 male generative cells of *B. alba* are equal to 100 female hybrids. 2) 100 female generative cells *B. dioica* plus 100 male generative cells of *B. dioica* are equal to 50 males and 50 females of *B. dioica*. 3) 100 female generative cells of *B. alba* plus 100 male generative cells of *B. dioica* are equal to 50 female and 50 male hybrids. From these data he concluded that the generative cells of *B. dioica* are progamously determined for a certain sex tendency, and that all female plants give only female generative cells (homogametic), while male plants produce male and female generative cells in 1:1 ratio. The sex is determined at the moment when the two generative cells unite (syngamously). As the male tendency is supposed to be dominant over the female tendency, the sex is determined syngamously as male when the zygote is heterogametic, or is determined as female when the zygote is homogametic. Thus, the mode of sex determination, according to Correns, follows the simplest rule of Mendel's law like the inheritance of flower colour of bean bastards. His explanation of sex determination by Mendel's law has been accepted by different other authors with more or less similar interpretations.

W. E. Castle (1909, p. 395) assumed a differential factor of sex which is alleromorphic to the absence of that factor. This factor is inherited as a Mendelian character dominant over its absence, and the presence of that factor means femaleness and absence of it means male.

W. Bateson (1913) repeated Correns's experiments with *Bryonia alba* and *B. dioica* and obtained the same results. But he gave them the entirely different interpretation that the *dioica* female has egg-cells of female and male nature, whereas the *dioica* male has pollen of male nature only. And the *alba* hermaphrodite has egg-cells both female and male, and pollen all female, i. e., the female is heterogametic and the male is homogametic. The female gamete is dominant over the male gamete.

G. H. Shull (1910, p. 110 and 1911, p. 329) found hermaphrodite mutants in his pure bred families of *Lychnis dioica*, which occur in a ratio somewhat less than 1:1000. Among four hermaphrodites which he had found, two proved to be somatic hermaphrodites and the rest were gametic hermaphrodites. These gametic hermaphrodites when used as pollen parents either for self-fertilisation or in cross with

females, produced both females and hermaphrodites. When they were used as pistil parents and fertilised by normal males, they produced females and normal males. From these data he agrees in general with those of Correns, and he confirms the homozygous nature of females and the heterozygous character of males.

It seems to me that the application of the Mendelian theory of sex determination is inadequate for the explanation of the phenomenon of sex transition in *Arisaema japonica*. In Correns's explanation of the case in *Bryonia dioica* and Shull's explanation in *Lychnis dioica*, the female individuals were regarded as homozygotes. But this explanation is not applicable to *Arisaema japonica* unless all the cormlets formed in the female corms produce at once the female sex instead of passing through the asexual and male states. Castle's hypothesis is also inapplicable, because all female corms of *Arisaema japonica*, which according to Castle's interpretation should always bear the female determiner, are actually reversed into males and even into the asexual state. Bateson's explanation seems also to be inapplicable for the explanation of the normal transition process of our plant, because all the male corms of *Arisaema japonica* could without a single exception be transformed into the female state.

F. Noll (1907, p. 1) proposed to explain the constant ratio of 100 males: 114.93 females (after Heyer) in common hemp plants. His schematic culture of *Cannabis sativa* from a single female plant showed that the morphological situation of the seeds in the mother plant has no relation to their sexuality. And he noticed that the larger the size of a mother plant and the greater the quantity of seeds, the nearer comes the sex ratio to the constant ratio. If there were some balancing factors in egg-cells, the sex ratio must be more or less near the constant ratio, even though a population of plants raised was from a small sized mother plant and, consequently, by the number of seeds borne, not great enough.

The sex ratios experimentally obtained from small sized plants were very different from each other, the one extremity being 16% female, while the other was 90.0% female, so that such an extreme difference proved to him the absence of a controlling factor in the female generative cells. He, then, pollinated many female hemp plants with pollen from a definite single male plant, from which he obtained a sex ratio of 100 male: 117.3 female very near to the constant ratio. He also pollinated a few female plants with pollen of the same

inflorescence, from which he got a sex ratio 100 male : 121.6 female. This proved to him that the sex determination is executed by the male sexual cells, and not by the female cells. His reasoning, based on the experiments above mentioned, induced him to the conclusion that the egg-cell has a female tendency only and that the pollen has a male tendency. But the male tendency in the pollen expresses itself in different strengths so that one half of the male tendency of the pollen is dominant over the female tendency of the egg-cell in such a manner that the offsprings become male, while the other half of the male tendency of the pollen is recessive to the female tendency of the female generative cells, so that the offsprings become female after mating.

E. Strasburger (1910, p. 427), from the phylogenetical view point, arrived at the same conclusion as Noll. According to his view, the male and female organs in the hermaphrodite moss plants are differentiated in the haploid soma, for which the reduction division takes no part in the sex determination. But in the higher dioecious *Sphaerocarpos* he found that the sex is already determined in the spores, so that he experimentally raised two female and two male gametophytes from the four spores produced by a single spore mother cell. He observed that in this dioecious moss the reduction division must have played the rôle of the sex determination when the spores were formed from a diploid somatic cell which was proved as monoecious by E. Marchals (1907, p. 765). However, he insisted that the differentiation of sex by means of the somatic cell division is phylogenetically prior to the process of sex determination by means of the reduction division, and he considered that the latter division was introduced in this plant as a means of producing dioecious protonema. Similarly, in the homosporous *Filices*, the reduction division of the spore mother cell has nothing to do with the sex differentiation of a gametophyte even in such groups which are inclined to have dioecious prothallia. In the homosporous ferns the haploid generation is hermaphrodite in which the sex differentiation takes place in the somatic tissue of the gametophyte. But in the higher heterosporous ferns the sexual differentiation takes place in the diploid sporophyte through the reduction division as a means of producing male and female spores. The same relation is carried over to the higher dioecious phanerogamic plants, so that the egg-cells are female and pollens are male only, which is contrary to the statements of some other authors that a part of the pollen is female and the other male, and that a part of the egg-cell

has a female tendency and the other part a male tendency. He assumed, as did Noll, two kinds of pollens as to the strength of sex tendency for the explanation of the dioecious condition of the higher plants. The female plant is produced when the egg-cell meets with a pollen of the weak male tendency, but the male plant is produced when the egg-cell meets with a pollen of strong male tendency.

On the nature of these sex tendencies, Strasburger (1910, p. 497) assumed that the male and female tendencies are simply qualitative and not quantitative. Noll (1907, p. 18) explained the existence of rudimental pistils in the male flowers of the hemp plant by the insufficient suppression of the recessive female tendency. Strasburger (1909, p. 507) observed in his experiments in *Mercurialis annua* cases of decrease in the strength of male and female tendencies. He obtained 907 seeds from female *Mercurialis annua* which were fertilised with pollen gathered from male flowers sparsely found on the female stock. From these seeds he grew 48 plants whose sex, without exception, was female. In another case (1910, p. 477), he obtained 15 male *Mercurialis annua* upon which a few female flowers were found. These female flowers were fertilised with the pollen of the male flowers on the same stock. The sex of the whole 36 plants raised from the seeds thus obtained were entirely male and they retained thence their sex. From these data Strasburger concluded that the dominance of the female sex in the former case and the dominance of the male sex in the latter case has to be ascribed to the enfeebled strength of the male or female tendency of the gametic cells on account of the dominant influence of the mother plant for the opposite sex condition (1910, p. 481). His report (1900, p. 657) on the female *Lychmis dioica* which was infected by *Ustilago violacea* is also interesting. This infected *Lychmis* produced stamens in the female flower. This phenomenon he considered as on the abnormality caused by the ferment of the mycelium which had penetrated into the embryonal tissue of the flowers. G. Bitter (1909, p. 120) found more or less the same results shortly before Strasburger with *Mercurialis annua*. His data proved to him the presence of male and female tendencies in diploid sporophytes; however, there occurs sometimes an increase in the strength of the weaker tendency. In short, Noll and Strasburger claimed the genetical and irreversible nature of sex in dioecious plants, admitting, however, that the opposite sexual expression may in rare cases be awakened by the influence of special stimulation, or by some inner condition.

When we apply this theory in order to explain the phenomenon of sex transition in *Arisaema japonica*, we find an agreement with the sex nature of the sporophyte in which both male and female tendencies are present in every diploid cell. However, on the other hand, we meet some difficulties when we consider the following point. According to this theory we must conclude that the sex condition of our plant was determined syngamously when the gametes were mated and that the sex condition must have continued through the afterlife of the corms. But this is not the case in our plant, for all the corms which were gathered in the forest or those which were propagated by division out of the female and male corms transformed their sexual state quite regularly from the asexual to the male state and then to the female state, where they stayed as long as they lived in normal condition, so that we may regard this phenomenon of sex transition in *Arisaema japonica* as a very normal and regular process.

Now, we must turn our attention to the question of sex determination and find out why the more or less marked dioecious condition of homosporous ferns is determined in their haploid generation, and why the dioecious state of the sporophyte of higher angiospermous plants is controllable under various extreme conditions. In other words, what is the cause of sex determination that "ohne meiotische Teilungen, innerhalb ihrer haploiden Kerne (I may here add, oder diploiden Kerne in den somatischen Sporophyten des Angyosperms) sich sexuell verschiedene Tendenzen abwechselnd äussern können"? (Strasburger 1909, p. 9.).

Strasburger's experiments on hemp and other dioecious plants showed no influence of the external conditions on the change of their sexual state. But he (1910, p. 473) met with an example of sex control in a strong male plant of *Mercurialis annua* whose vegetative shoots were severely cut down. The plant produced two branches, bearing male inflorescences. However, he found two female flowers in one of the inflorescences and one female flower in the other. He met also with a case of sex reversion in the female plant under similar treatment. He observed that it is doubtful whether these results may be attributed to the severe cutting of the vegetative shoots or not, on account of the absence of proof that this plant should not have produced the female organ without cutting (1910, p. 476).

E. Laurent (1903, p. 689) studied the action of mineral matter upon the determination of sex in spinach. He cultivated this plant

under different soil conditions and observed that the general condition of nutrition directly influenced their sex condition, and that certain mineral elements produced also an influence on the sex of the embryos. An excess of nitrogenous compost or lime gave a large percentage of male plants, but potash and phosphoric acid favoured the development of female individuals. From the seeds produced by the plants which were cultivated with an excess of compost, he got a smaller number of male plants and a greater percentage of female plants together with monoecious individuals bearing a great number of female flowers. But from the seeds produced by the plants which were cultivated with an excess of potash, phosphoric acids, or much lime, he got a greater percentage of male plants, as well as dioecious and monoecious individuals with a greater number of male flowers.

K. Fujii (1895, p. 275) was the first Japanese investigator who treated the sex problem experimentally in phanerogamous plants. He noticed in various localities that *Pinus densiflora* produced a great number of female or hermaphrodite flowers in the position of male flowers and that the formation of such flowers was in a great measure limited to the long shoot which was transformed from a dwarf shoot of the last year. He pollarded two specimens of young *P. densiflora* in July. Among 45 branches thus treated, 9 branches produced female or hermaphrodite flowers in the position proper to the male flowers; out of 21 branches with marks of previous injuries, the shoots of five branches produced female or hermaphrodite flowers in the position proper to the male flowers and out of 2283 branches which were neither pollarded nor had any marks of previous injuries, only 7 branches produced shoots provided with female or hermaphrodite flowers in the positions proper to male flowers. In his opinion, the sex of *Pinus densiflora* is not determined by the morphological position of the shoots, nor is it determined until a certain stage of their development is reached. The determination is caused by the local increase of nourishment at a certain stage, or during certain stages, of its development, and the quantity and the quality of the nourishment are specific according to the biology of the species. He did not observe any case of transformation of female flowers into male ones.

C. Correns (1908b, p. 661) observed in the gynomonocious *Satureia hortensis* that the relative number of female and hermaphrodite flowers in an inflorescence is highly related to the external condition. Under bad nutritious conditions, or insufficient light supply, the number of

female flowers is remarkably reduced; and also the periodicity of flowering of the female and hermaphrodite flowers were disturbed. Hinderance of fruit setting by systematic cutting of the young fruits before they begin to ripen, turned the sex of the subsequent flowers to female flowers only. On this remarkable example respecting the positive influence of the food supply on the sexual expression, he observed that these conditions are to be regarded as a mere associated controlling factor, and that the plant has already the inner tendency for a certain sex when it is in the embryonal stage.

J. Tournois (1911, p. 1017 and 1912, p. 297) made observations on the abnormal flowers of some *Humulus japonicus* S. et Z. and *Cannabis sativa* which were obtained by early sowing on Feb. 1 and 15. He kept the germinated seedlings in a green-house until the end of March and then set them out in open lots. Flowers of these plants appeared twice in a vegetative period. The first flowering began already in the beginning of May, and the second flowering occurred in the normal season. In *Humulus japonicus* he enumerated 14 flowers on the 1st of May and 19 flowers on the 15th of that month. Among these flowers he found two male specimens which were sexually abnormal, some transforming their stamens more or less into the carpel in such a manner that certain stamens gave the appearance and construction of stigmas, or that some others transformed their pollen sacs into ovaries containing a massive undifferentiated cell tissue which was surmounted by stigmas. In *Cannabis sativa* he found in the flowers some transformation of ovules into stamens, or staminoidal transformation of stamens, or the sterility of pollens or of ovules. For example, a normal well differentiated ovule surmounted by two stigmas was found attached to a more or less developed pollen sac. These abnormal flowers were only observed at the beginning of the first flowering season.

W. Figdor (1911, p. 689) described more or less abnormal flowers in some dwarf specimens of *Humulus japonicus* S. et Z. The abnormal flowers were limited to the male individuals, in which stigmas were found upon anthers, filaments, or even upon the connectives. Frequently one or both of the pollen sacs were transformed into the macrosparangium. The sex of seedling plants raised from seeds of this kind were all feeble males. Sometimes, the abnormality of the male flower attained an extreme degree so that apparently normal pollen was found in the pollen sacs attached to the stigmas. These abnormal hermaphrodite flowers were seen among male flowers (andromonoecious) or mixed with

male and female flowers (monoecious) or mixed with female, male, and hermaphrodite flowers in the same individual (comonomoecious). However, there were found no abnormal pistillate flowers. He reported that only those hermaphrodite flowers were seen in the extremely dwarfed specimens which were stunted in their growth through a certain chemical light intensity, a comparatively low temperature, or a lack of humidity in the air combined with poor nutrition.

J. H. Schaffner (1923, p. 73) reported on the results of his cultivation of the Japanese hop plant in a greenhouse during the winter of 1920-1921. The seeds were sown December 8, 1920, and the plant began to bloom six weeks later. Among 22 plants, thus obtained under glass, six of them were staminate and all showed reversion to the carpellate condition. The remaining 16 plants were carpellate and of these seven showed reversion to the male condition. The important factor in causing the reversion of the sexual state, seemed to be the short daily illumination together with very rich soil in which the plants were grown.

F. G. Pritchard (1916, p. 325) reported unmistakable evidence of sex alternation due to the influence of external stimuli. He mutilated male, female, and monoecious specimens of *Cannabis sativa* by removing flowers, flower buds, leaves, and varying proportions of stems; or he treated the plants with top bagging, or he injected various chemicals into them. Through removal of the flowers he obtained the following results:—he found only three pistillate flowers. Among those male flowers which appeared on the 17 male plants, after the manipulation, while in the female plants there were abundant flowers containing both stamens and pistils. In fact, the proportion of monoecious plants bearing staminate flowers on the female plants was greatly increased. He explained this phenomenon on the basis of the food theory of sex determination by supposing that the removal of flowers and flower buds, when their reserved food was consumed down to a minimum quantity, causes the diminution of the development of new female buds and evokes the development of male flowers.

J.H. Schaffner (1919c, p. 311) succeeded in breaking up completely the dioecious condition of hemp plants. He planted common hemp in the winter, when light conditions were very low, on shallow greenhouse benches heated mainly from beneath. Under such conditions there appeared a great many (50-90%) reversions and confusions of sexuality in both the staminate and carpellate plants. A number of carpellate plants began gradually to change their sex until finally

normal male flowers only were produced. The tendency of sex reversion under such conditions is from female to male. But few staminate plants developed carpellate structures even at a later stage unless they had a tendency to produce female flowers from the beginning. He admitted the epigamic determination of sex and ascribed the cause of sex determination to the physical and chemical stimuli of various kinds which reacted on the soma of the sporophyte.

W. Ried (1922, p. 259) experimented under various light conditions and by water culture studying the influence of various fluids on the sexual expression of *Zea Mays*. He observed that by a scanty supply of food materials the plant can be induced not only to incline toward maleness but toward femaleness also, and he stated that the accumulation of a larger quantity of assimilation products resulted in an increase of female inflorescences, and a smaller quantity of assimilation products induced in them a greater production of male flowers. In the field plot experiment he raised by dense sowing various grades of vegetative growth of the plant. Some plants which germinated earlier than others enjoyed greater room of rooting and greater amount of sunlight so that they came to suppress the growth of individuals which were delayed in their germination. Among this population it was generally the case that the individuals which had the higher ratio of development in the bulk of stems to that of roots tended toward female expression. He claimed that the degree of shifting of the sex ratio for femaleness or maleness of the plant depends on the surplus quantity of the assimilation products accumulated over the mineral salts absorbed, and he believed that this surplus quantity of organic substance did not react directly on the hermaphrodite *Anlage* of the flower, but stimulated it indirectly to produce male or female sex hormones.

With regard to the cryptogams, a great many data are reported on their sex conditions together with the experimental control of sex.

E. D. Wuist (1910, p. 216) derived monoecious prothallia from female prothallia of dioecious *Onocles Struthiopteris*. She transferred large heart-shaped female prothallia into Beijerinck's solution out of soil culture. After four to seven days a number of monoecious prothallia were found in which antheridia were developed on the marginal tissue of the prothallia near the notch. She also got monoecious prothallia by giving rise to some antheridia upon adventitious tissue of the old neglected female prothallia. Moreover, she produced monoecious prothallia derived from female gametophytes by transferring them from

distilled water to Knop's solution, or from Knop's solution to Beijerinck's solution lacking potassium dihydrogen phosphate, or from Sachs' solution with 1% potassium phosphate to Knop's solution. She attributed these results to a certain reaction of mineral salts and light intensity cooperating toward the formation of male organs on the female prothallia. She found no monoecious prothallia from male gametophytes during her experiments.

D. M. Mottier (1910, p. 209) observed also about 12% monoecious gametophytes of *Onoclea Struthiopteris* in soil culture under favourable conditions. He reported an interesting case of monoecism in this plant where some female prothallia, which continued growth without bearing sporophytes, sometimes developed numerous small lobes in the older portion upon which numerous antheridia appeared. He noticed that the monoecism of fern prothallia was limited to archegonial prothallia, and no monoecious prothallia were ever reported induced from antheridial prothallia. From this point, he insisted upon the predetermination of the sex of the spore and claimed that conditions of nutrition do not determine the sex of the gametophytes during their development, but that those conditions cause only some modification by stimulating the opposite sex tendency in a latent state.

G. Perrin (1911, p. 197) reported that among heart-shaped archegonial prothallia of *Equisetum arvense*, *E. silvaticum*, and *E. palustre* monoecism is frequently found. In those prothallia antheridia were distributed in the peripherous region or sometimes upon the adventitious lobules from the old prothallia of *E. arvense*. He observed that nutrient relation was very influential upon the sex differentiation.

K. Goebel (1910, p. 671 and 672) has another explanation for the sex differentiation of fern prothallia. Usually the monoecious prothallia develop male organs first, and after the accumulation of complicated organic compounds, follows the archegonial formation. Oftentimes the formation of archegonia can be inhibited by want of C-, N-, and P-assimilation. The female prothallia of *Equisetum* were induced to change to male prothallia by bad nutrition. He interpreted these phenomena as showing that the male sex acts as an inhibitor of the female sex, and, in the same way, when the inhibition prevailed from the time of spore formation, then macro- and microspores are produced.

I. Nagai (1919, p. 157) made cultures under various nutrient and light conditions of monosporangiate prothallia of *Blechnum nipponicum*, *Woodwardia radicans* var. *orientalis* and *Adiantum pedatum*. He found

two monoecious prothallia among 20 monosporangiate prothallia of *Blechnum nipponicum* on which archegonia and antheridia were distinctly localized, corresponding to the condition of the growth of prothallia. Also, he experimentally induced the formation of some antheridia upon the adventitiously grown portion from the cut margin of archegoniate prothallia of *Woodwardia radicans* var. *orientalis*. He explained these phenomena by supposing the existence of antheridia producing and archegonia producing chemical substances, by either of which, if one sex is determined, the other will be inhibited. The germinated spores are able to produce those determiners, but the formation of archegonia and antheridia is controlled by the formative stimuli of the external conditions under which the prothallia are grown.

From these valuable experiments of various authors which I have summarised above, we know that there are numerous dioecious plants which had been deemed as fixed and unchangeable by outward influences, but which are, in fact, controllable if we are able to apply a certain fitting treatment and that the dioecious state of those plants is a relative condition and not an absolute one. In nature also, there are kinds of plants in which the sexual state proper to the species is changed in various ways.

L. Wehrli (1892, p. 245) reports an example of complete transformation of male catkins of *Corylus Avellana* into female catkins. The transformed male catkins looked red on account of the formation of the red gynaeceum in place of yellow stamens. The anthers of the abnormal flowers were turned into staminoidal bodies representing every intermediate form between pistils and stamens. Such abnormal flowers, however, were limited to male flowers only, and no female flower in this peculiar shrub showed abnormality.

G. Camus (1904, p. 87) observed on the river bank of the Marne that some branches of *Salix undulata* and *S. hippophaefolia* bearing male catkins were changed to bear female catkins only or mixed with male and female catkins the next year. Such transformation was also found on the river bank of the Seine and of the Oise, but less frequently. He witnessed that the water level of the river Marne was high so that the willows growing on the lower bank were all submerged for a comparatively long time. Those transformed specimens were almost confined to the branches of submerged individuals. In this case, therefore, it may be regarded that the sex transformation from the male sex to the female was provoked by the injuries of submergion.

J. E. Higgins (1916, p. 208) reported a case of the appearance of a female sprout out of a male tree of *Carica papaya* whose trunk had been cut off at the basal part near the ground. Sometimes this plant, when thus treated, bears hermaphrodite flowers. However, such transformation takes place with no certainty or regularity, and the seedlings raised from seeds of selfed hermaphrodite flowers were observed to consist of 94% of fruit bearing trees which were either pistillates or some form of hermaphrodite plants.

A. J. Davy and C. M. Gibson (cited from Yampolsky, 1920a, p. 29) have found in *Myrica* (normally dioecious) many gradations between the normal pistillate and staminate types. They also described shrubs and shoots whose sex varied from year to year. Fourteen cases found to be entirely pistillate in 1913 and 1914 produced staminate catkins the next year. One plant produced almost entirely staminate catkins. Certain trees and branches which produced abundant fruit in 1913 developed mixed shoots in 1914, and in 1915 became almost staminate.

T. Makino (1904, p. 92) reported that he has observed some female trees of *Morus nigra* in which some female catkins were mixed with male flowers, and in an extreme case all catkins of a tree were converted into male catkins.

J. H. Schaffner (1919a, p. 409) described an example of intergradation in the dioecious *Morus alba* and *Salix amygdaloides*. Sixty-six trees of *Morus alba* which came under his examination graded from apparently pure carpellate to pure staminate. Twenty-eight of them were pure carpellate, 24 were pure staminate and 14 were intermediate. Among these intermediate cases an example of sex reversion from male to female is reported. The main trunk producing male catkins, suddenly produced a bud having a female tendency which was persistent in its secondary buds and branches. The seeds upon the reversed branch were viable and little trees were grown from them. We would be much interested if we could know the sex proportion of these seedlings in *Morus*. He also examined 100 *Salix amygdaloides*, in which 9 individuals were intermediates. These 9 individuals were perhaps staminates and became intermediates by the appearance of a certain number of monosporangiate or bisporangiate catkins. The localisation of staminate and carpellate flowers in a catkin is interesting. In most cases staminate flowers were situated below and carpellate flowers above. On the transition zone of staminate and carpellate flowers there frequently appeared hermaphrodite flowers.

The same author (1919b, p. 25) also described 22 intermediate forms between pure staminate and carpellate *Thalictrum dasycarpum*, ranging in delicate grades, where, in a staminate plant, numerous carpellate flowers were seen; while, on the other hand, among pure staminate flowers a single intermediate flower was observed in which a single carpel was found; likewise, in a carpellate plant, a single intermediate flower was noticed in which a single stamen was contained. He states that the male or female state of this plant is established by some physiological state of the cell or tissue at the inception of the sporophyllus of the flower. He compared such a tissue to a delicately poised balance in which a slight internal physiological difference will tip the beam in one direction or the other.

Recently, the same author (1922, p. 72) has published an interesting account on the sex control of *Arisaema triphyllum* and *A. Dracontium*. His results in *A. triphyllum* were that the nine staminate plants retained the same sex in the next year, but they turned to carpellate plants in the succeeding year. Five intermediate plants became staminate plants in the next year, but in the following year four of them became carpellate and the remaining one retained the same sex. Twenty five carpellate plants were turned in the next year into 21 staminate, 2 carpellate, and 2 intermediate plants, but in the following year they consisted of 22 carpellate, 1 staminate, and 2 intermediate plants. Further, he experimentally treated this plant by various methods for the purpose of proving the unfixed nature of its dioecious condition together with the purpose of sex control. The results agree generally with those of my own experiments. In andromonoecious *A. Dracontium*, he treated three monoecious and seventeen staminate plants. One of the monoecious corms was transformed into a staminate, and the staminate plants turned monoecious. Thus he could reverse staminate plants into monoecious and monoecious plants into staminate ones.

Intersexualism, found in the interesting series of gynandromorphism in the interracial crosses of *Lymantria disper* (R. Goldschmidt, 1916, p. 55), or sex intergrade, applied to mean the variable gradation mutantly produced in the 131st generation of isolated cultures of female *Symocephalus vetulus* (A. M. Banta, 1916, p. 578), are subjects worth to be studied in the plant world as they are related to the question of sex determination of dioecious plants.

A. B. Stout (1919, p. 109) studied the gynodioecious condition of *Plantago lanceolata* and found it difficult to express the typical flower

type of an individual plant. Various grades of development of stamens, as in length of filaments, in size, in shape, indehiscence of anthers, in the amount of sporogenous tissue, and in the total number and variability of microspores, were produced. Such gradations were found in various flowers of a single plant or even among stamens of a single flower. In the female flower there are found some physiological differentiations, measured by seed production, such as the impotent pistils of a certain pistillate plant. Generally, the female flower is highly fruitful, while the hermaphrodite type is low. From this phenomenon of intersexuality in gynomonocious plants he concluded that neither hermaphroditism nor dioecism are fixed conditions for species or for individuals as such. The maleness and femaleness are subject to such variability; they are even reversible, and the physical and chemical substances involved modify the sex condition in their ontogeny.

C. Yampolsky (1919, p. 410) made a pedigree culture of male *Mercurialis* plants to F_2 generation and of female ones to F_4 generation. The plants used for his experiments were prevailingly male or female. The offsprings of selfed males were of male sex and those of selfed females were prevailingly or purely female. But the sporadic appearance of the opposite sex could not be taken off through the pedigreed generations. He insisted that this intersexualism can be recognised as a condition in the plant and that the varying ratio of sporadic flowers of the opposite sex is explained by the graded potencies of female and male gametes. He (1920b, p. 95) reported also on the phenomenon of intergradation of hermaphrodite flowers in female and monocious *Mercurialis* plants. He noticed that this so-called monocious *Mercurialis* was initially a female plant, but as the plant grew older, the male or hermaphrodite flower appeared. From these points of view he emphasized an epigenetic nature of sex determination rather than the view that the sex condition is decidedly fixed by the presence of definitely localized qualitative factors.

On the other hand, the sex ratios are often used as a standard for the solution of the sex determination problem considering that the cause of sex determination must be related to the reason why the ratio appears in constant value, or to the reason why this constant ratio is modified under certain conditions. All the theories based on this constant ratio, which must be very near the ideal sex ratio 1:1, are summoned up from a presupposition that male and female generative cells have sex determining factors or tendencies, whose properties are

more or less similar to the Mendelian factors, and that the sex is syngenetically determined when they are united under the probable chance 1:1. The modification of the constant ratio results from the unequal chances of union of male and female gametes.

Th. Ciesielsky (cited from P. J. Wester, 1914, p. 207) fertilised three potted female hemp plants with pollen from just dehiscing but not yet fully opened anthers. Out of 120 seeds thus obtained, he raised 112 plants which consisted of 6 females and 106 males. The other female plants were fertilised with pollen taken in the morning and kept in a paper bag until evening. The 89 progenies raised from these seeds were all females, showing a strong contrast to the former.

His results were disproved by F. Lilienfeld (1921, p. 296) owing to the larger proportion of females in both of the progenies from fresh and stale pollen. He interpreted Ciesielsky's result with the different power for survival of female or male determining pollen, during storage in paper bags.

C. Correns (1918, p. 11975) was of the opinion that the different physiological characters of male and female determining pollen, in which different speeds in the growth of the pollen tube to reach the ovules result in a control of the sex ratio. He reported that he secured 31.65% of male *Melandryum* plants among 2,256 progenies which were produced from seeds in the capsules fertilised with much pollen, but, in the other case he secured 43.78% of male plants among 2,377 progenies which were produced with seeds from capsules fertilised with scanty pollen. The difference was 12.13%. He (1922a, p. 188) secured 46.07% of male plants out of 1,706 progenies raised from seeds situated at the lower portion of the capsules, and 34.23% of male plants among 1,204 progenies raised from seeds situated at the upper portion of the capsules. He explained this result by saying that male and female pollen are physiologically different, at least, and that the female determining pollen sends out its generative nucleus to the ovules quicker than the male determining pollen.

Lately, the same author (1922b, p. 1049) found in *Melandryum* that there are different kinds of pollen grains in their physiological nature shown by the different resistance to alcohol vapour. He stated that this different nature of resistance may be recognised as one of the characters belonging to the male or female determining pollen respectively. He used four female plants as seed parents and one male plant as the pollen parent. A part of the fresh pollen was used as

the control, while the other part of them was brought into the vapour of 94% alcohol. The sex ratio obtained from the seeds in the capsules which were fertilised with the pollen treated with alcohol vapour for 40 to 60 minutes showed more inclination to the male individuals than that of the ratio obtained from capsules fertilised with normal pollen so that male individuals were proved to produce 15.92% more.

It is quite natural to presuppose, if the sex is determined by some factor or tendency more or less similar to the Mendelian factors, that the sex ratio of a certain plant species will appear quite constantly. But the case of sex ratio of *Arisaema japonica* is quite different. The ratio of this plant changes every year until all the corms in a group are turned into females only (Tab. II, III, and IV). In such cases, the sex ratio means nothing more than a temporary accident. This temporary nature of the sex ratio makes us suppose that the sex factors or sex tendencies of *Arisaema japonica*, are not like those which determine the sex by their presence or absence, but the sex is determined by some relationship between them and controlled by the varying inner and outer conditions of life.

Thus, contrary to the belief that the sex is determined indifferently to the influence of nutritive, climatic, or like conditions, (F. Noll, 1907, p. 3 and 11) and in opposition to the syngenetic theory of sex determination, many data have been accumulated which support the epigenetic theory of sex determination. It seems to be true that the cause of sex determination in *Arisaema japonica* agrees with the epigenetic theory of sex determination rather than with the theory of syngenetic determination.

I think, however, that for the general understanding of the cause of sex determination in *Arisaema japonica*, we must accord the primary importance to the phylogenetical view-point. One of the critical points of the phylogenetical argument on the evolution of dioecious condition is the question whether a macrospore or microspore which has been raised from the somatic tissue of a sporophyte has a female or a male tendency or both. Strasburger (1910, p. 433) says, "Sie (Geschlechts-sonderung) stellt sich an letztern (diploid Sporophyte) nicht erst während der Reduktionsteilung der Gonotokonten, wie bei den diöcischen Moosen, ein, sondern schon bei den Entwicklungsvorgängen, die zur Bildung der Gonotokonten führen, sodass diese bereits männlich oder weiblich sind".

Allen (1919 p. 289), Winge (1923), Kihara and Ono (1923, p. 147), Santos (1924, p. 353) have reported on the discovery of sex chromosomes in *Sphaerocarpos*; *Humulus lupulus*, *H. japonicus*, *Melandrium album*, *Vallisneria spiralis*, *Rumex Acetosa* L., *Elodea canadensis* respectively. However, as we do not find any kind of such chromosomes in our plant, we cannot look for a corroboration of our view-point by accepting as a basis the different nature of the germ cells.

Schaffner (1918, p. 109) also opposes the idea that the generative cells are determined as female or male gametes by the sex determining factors. He insisted that spores and gametes bear both male and female tendencies, so that the spores of ferns produce hermaphrodite prothallia in which both sexual organs are formed by the activity or latency of hereditary male or female factors in spores.

It may be more natural to assume, especially in the case of *Arisaema japonica* in which male or female conditions appear in one and the same plant according to the normal process, that the microspores and macrospores bear both the male and female tendencies in an equal potency and that the somatic cells of the sporophytes bear, naturally, male and female tendencies in the same state. The author finds no contradiction of Correns's statements, "dass selbst die Schwesterzellen von Spermatozoen und Eizellen noch die gemischtgeschlechtige Tendenz besitzen, und damit gewiss diese Keimzellen selbst auch, obwohl sie eine männliche oder weibliche Rolle bei der Fortpflanzung übernommen haben" (1920, p. 54). He is also of the same opinion with regard to the sexual expression of his plant as Yampolsky (1920a, p. 30 and 31) who inferred from his *Mercurialis* experiments that "there is nowhere evidence that sex is determined in this plant by the presence or absence of a sex determining factor. Those individuals which remain purely male or purely female throughout are not to be conceived as very different from those which produce few flowers of the opposite sex. There is no evidence for the localization of the sex difference either in a special part of the plant or in a special part of the cell".

Dioeciousness in higher plants is revealed by the unisexual states together with the sex dimorphism as the secondary sex character. In some plants, for example hemp, we can tell the sex of an individual plant before it is blooming by the conspicuous morphological and physiological dimorphism associated with the sex. This fact shows that the sex potency is dominantly determined in the embryonic stage so that their sex characters are evidently impressed early in their vegetative

stages down to their blooming time. But this view is not true in *Arisaema japonica*. In this plant there is no evident difference between the male and female plants, nor have we any evidence to assume that a corm is primarily determined as a male or female plant, or that, in other words, the corm has any prepotency for either the female or the male sex. On the contrary, we are forced to assume, by the results of the experiments, that the sex potency in this plant is bestowed anew yearly, and not that it is permanently determined as female or male from the beginning. Therefore, the dioecious condition in *Arisaema japonica* means merely that the plant is congenitally or hereditarily fated to make up a monosporangiate spadix when it reaches the vegetative stage of the formation of the apical flower bud for the next year, and nothing more. This stage of flower formation is the last step in the life cycle of the vegetative activity of the plant, so that we may say that the sex potency of the corm is expressed as the résumé of the whole vegetative life.

Here, we are invited to presume by the numerous examples of abnormal sex conditions or intersexualism which have been experimentally or accidentally observed in various plants, that such confusion in their sexual state is no more than the morphological expression of an inner finely balanced state of male and female tendencies, so that the changing conditions of vegetative life easily tip the tongue of the balance to one side or the other. The phenomena of sex transition or retro-transition of sex favours this view.

So far as present knowledge goes, it is not very clear whether the influence of outer conditions can change the strength or the quality of the sex tendency of the spores or not; but we may believe, at least, that the influence of outer conditions not easily affects the genetical nature of the plant species. The experimental control of the sexual state, induced by extreme physiological conditions, may be regarded as a mere temporary reversion of the hereditary nature of sex condition and not the breaking down of the hereditary nature. This relation is analogous to the varying flower colour of garden *Hortensia* under varying outer conditions, even though the external influences can not change the flower pattern of the phylogenetical nature. In *Arisaema japonica* I have proved the phenomenon of sex transition experimentally. Lighter corms are male and heavy corms are female without fail, and the sexual state moves on from the asexual state to the male state and lastly reaches the female state and stays therein. This special property can

never be understood as caused by mere influences of outer conditions, but must be ascribed to the inherent character of the plant. Therefore, the successful results of sex control by the author, and also by Schaffner, may be regarded only as a mere temporal disturbance of the hereditary process of sex transition.

However, we must here assume a modifier which serves to act on a certain balanced state of sex condition and transfer it to the other balanced state. As this modifier, I would like to consider the quantity of formative assimilation products. There are three reasons for this assumption, first: this plant usually develops a male spadix from a lighter corm and a female spadix from a heavier corm; second, it is easily conceivable that the whole reserved material in a corm is almost solely used for the development of an apical bud on account of its uniaxilar character bearing one terminal spadix only; and third, the heavier corm usually develops a large sized vegetative organ, and hence the quantity of formative assimilation products may be supposed naturally to be greater.

I think that sex transition does not mean a plus or minus of strength of sex tendencies contained in cells or the breaking down of either of these tendencies, because the former sexual state can easily be recovered by the plus or minus of formative assimilation products. Many examples, including the cases of partial or complete change of normal sex condition, to which some citations were made above may be said to be due to influences of outer conditions on the hereditary balanced sex potency of the plant in question. There may be differences of direction of sex changes so that the sex state of a plant may easily be changed from female to male or reversely. Or there may be different grades of difficulty in sex control. All of these specializations can be attributed to the relation of their hereditary potency and to the quantity of formative assimilation products which affects their potencies as sex modifier.

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 Fig. 23. Longitudinal section through an incipient male spadix, x 20 (Aug. 4).
 Fig. 24. Ditto, x 20 (Aug. 4).
 Fig. 25. Longitudinal section through an *Anlage* of a male apical bud after removal of its protecting bracts, x 20 (Aug. 4).
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