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Chromosome Arrangement in the Meiotic Divisions in Pollen Mother Cells of *Rhoeo discolor*, HANCE[1)]

By

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With 30 Text-figures

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In the heterotype metaphase in pollen mother cells of *Rhoeo discolor*, the chromosomes are found conjoined with one another to form a ring (KATÔ, 1930), and there is no definite arrangement of the chromosomes in definite patterns, the free movement of each chromosomes being prevented by its conjoinment with the others. In the heterotype anaphase and homotype metaphase, however, the chromosomes are quite free from one another and arrange themselves on a plane into definite configurations. In the homotype metaphase, they are V- or J-shaped, and the configurations of their arrangement seem, at the first glance, to be manifold, but if we take only the point of spindle fiber attachment in each chromosome into consideration, the arrangements can be classified into several different types, as is the case with *Vicia faba* (MAEDA and KATÔ, 1929).

OBSERVATION

Arrangement of Chromosomes in the Heterotype Anaphase

When the chromosomes are freed from one another in the anaphase

1) Chromosome Arrangement XI.

by the breaking of their conjoinment, and approach towards the poles, they are longitudinally double owing to their longitudinal fission, taking the shape of an X, and assume various configurations of arrangement. Although the normal number of chromosomes in this plant is 6, such abnormal numbers of chromosomes as 5 or 7 are often found as the consequence of unequal distribution of the chromosomes towards the poles. In the following description each case of chromosome number, 6, 5 and 7 will be given separately.

The Case of 6 Chromosomes

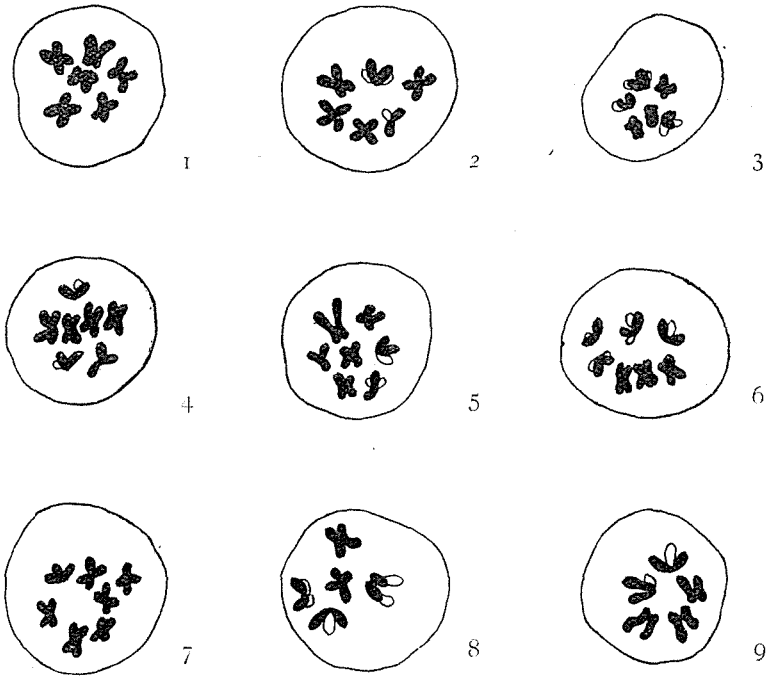
In this case, the configurations of arrangement can be classified into two distinct forms, as shown in the diagrams in Table I (Form I and Form II). Intermediate or transitory forms which do not fall into either of these forms are grouped together as Form III.

TABLE I

The case of 6 chromosomes in the heterotype anaphase. Solid circles indicate the positions of the chromosomes in the arrangement.

Form	I 	II 	III Interm.	Total
Number of occurrence	58	47	9	114
Percentage	50.9	41.2	7.9	100

In Table I, we see that Form I which resembles the stable form of arrangement of MAYER's floating magnets (Fig. 1) is greater in frequency of occurrence than Form II, in which all the chromosomes are arranged in a ring having none of them inside it (Fig. 2). The frequency of occurrence of intermediate forms (Form III) is rather small, being only 9 out of 114 cases.



Figs. 1—9. Arrangement configurations of chromosomes in the heterotype anaphase.

The Cases of 5 and 7 Chromosomes

The results obtained from the cases of 5 and 7 chromosomes are given in Tables II and III.

TABLE II

The case of 7 chromosomes.

Form	IV 	V 	VI 	VII Interm.	Total
Number of occurrence	1	8	2	1	11
Percentage	8.3	66.7	16.7	8.3	100

In the case of 7 chromosomes, the majority of the configurations

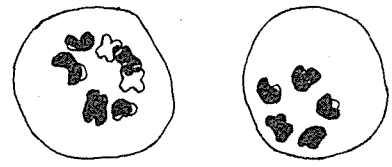
belong to Form V in which 6 chromosomes are arranged in a ring having the seventh in its center (Fig. 5). Form VI in which all the 7 chromosomes take part in the formation of the ring comes next in frequency (Fig. 6). The configuration in which 5 chromosomes take up positions on a ring and the sixth and seventh occupy the inner positions inside this ring (Form IV), and configurations which are intermediate or transitory (Fig. 7) were found respectively in only one case.

TABLE III

The case of 5 chromosomes.

Form	VIII 	IX 	X Interm.	Total
Number of occurrence	5	24	0	29
Percentage	17.2	82.8	0	100

In the case of 5 chromosomes, as shown in Table III, Form IX in which all the 5 chromosomes make a ring having none inside it (Fig. 9) occurs more frequently than Form VIII in which 4 chromosomes make a ring having the fifth in its center (Fig. 8). The frequency of occurrence of the former form is 82.8% of all the cases observed.



10*a* 10*b*

Fig. 10. Arrangement configurations of chromosomes in two sister groups in the heterotype anaphase. *a*) 7 chromosomes of which 2 lie in a different plane from that of the other 5. *b*) The sister group with 5 chromosomes.

In both Tables II and III are excluded those forms of arrangement, such as are shown in Fig. 10*a*, in which only 5 chromosomes out of 7 arrange themselves on a plane, the remaining 2 lagging ones lying under that plane.

In summing up the results obtained in the heterotype anaphase it can be said that the first maximum of frequency of occurrence is found in any case of chromosome numbers 5, 6 and 7 in the configuration resembling the stable form of arrangement of MAYER's floating magnets.

Arrangement of Chromosomes in the Homotype Metaphase

The chromosomes in the homotype metaphase are more slender and larger than those of the heterotype metaphase and anaphase. There are 6 atelomitic chromosomes of which 2 are subterminal and the others approximately median. They are arranged in the nuclear plate directing their points of spindle fiber insertion towards the center of the arrangement configuration. All the configurations observed were examined only with respect to the position of the point of spindle fiber insertion.

The Case of 6 Chromosomes

As is seen in Table IV, configurations belonging to Form XII in which 5 chromosomes are arranged in the form of a ring having the remaining one in its center (Figs. 11 and 12) occurs markedly oftner than Form XIII in which all the 6 chromosomes are arranged in the form of a ring having none inside it (Figs. 13, 14 and 15). This form of arrangement forms the first maximum, the frequency of occurrence expressed in percentage being 47.5. In Fig. 15, a chromosome with subterminal spindle fiber attachment, stretches its arms out into a nearly straight rod across the equatorial plate. The point of spindle fiber attachment of this chromosome (marked ×) lies on the ring consisting of the points of spindle fiber attachment of the other 5 chromosomes, The word "ring" is of course not used here in its

strict sense. Owing to the relatively small size and the semicircular shape of the cell in which the long chromosomes are confined, the arrangement configurations are generally elliptical rather than circular. Form XI in which 2 chromosomes are surrounded by the remaining 4 is an unexpected configuration and is very rarely found (Fig. 16). No such configuration was met with in investigations with *Spinacia* and *Vicia*, both of which also carry 6 chromosomes in the homotype division (MAEDA and KATÔ, 1929). Besides these three types there are other configurations differing from any of them, and they are grouped together into Form XIV (Figs. 17, 18, 19, 20 and 21). The highly frequent occurrence of this form as compared with Case IV in *Spinacia* seems to be due to the difficulty which long chromosomes have in taking their proper position in the arrangement in the relatively small confined space.

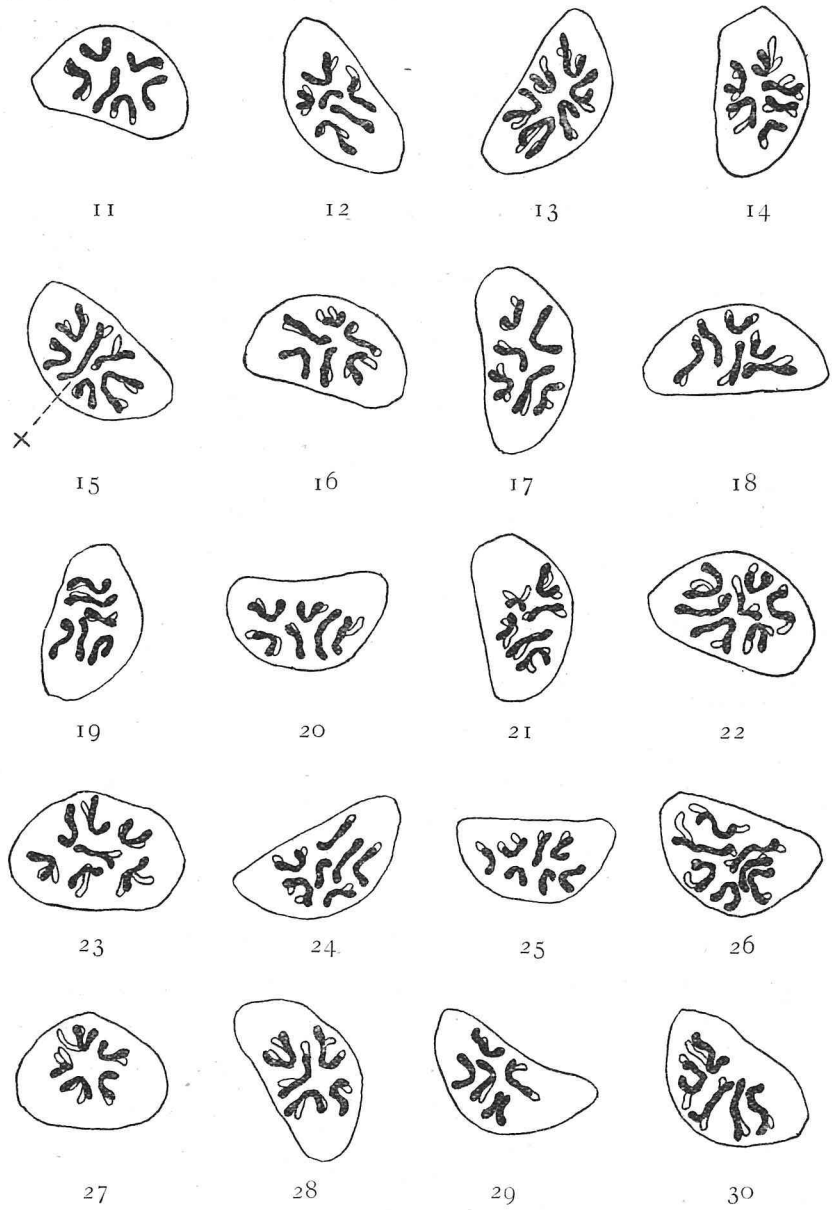
TABLE IV

The case of 6 chromosomes. The dots on the rings in the accompanying diagrams indicate the position of the point of spindle fiber insertion in each chromosome.

Form	XI 	XII 	XIII 	XIV Interm. and irregular	Total
Number of occurrence	4	103	59	51	217
Percentage	1.8	47.5	27.1	23.5	99.9

The ratio between Forms XII and XIII in Table IV is 1.8 : 1, while in *Spinacia* the corresponding ratio is 2.4 : 1. The comparison of these ratios shows that the arrangement configuration of chromosomes in *Rhoco* resembles the arrangement of MAYER's floating magnets to a less extent than in *Spinacia*. This decrease in the degree of resemblance seems to be due to the fact that while in *Spinacia* the small round chromosomes have a relatively ample space in which they

can move about freely, in *Rhoeo* the long chromosomes have to move in a relatively small space.



Figs. 11-30. Arrangement configurations of chromosomes in the homotype metaphase.

The Cases of 5 and 7 Chromosomes

The results obtained from the case of 7 chromosomes are tabulated in Table V. In this table, we see that Form XVI in which 6 chromosomes take up their positions on the peripheral ring of the chromosome arrangement having the seventh in its center (Figs. 22 and 23) is of most frequent occurrence, 48.7% of all the cases observed belonging to this form. Another form in which 5 chromosomes form a ring and the remaining 2 occupy inner positions inside the ring (Form XV, Fig. 24), and the form in which all the 7 chromosomes form an empty ring (Case XVII, Fig. 25) are of less frequent occurrence, their frequency values being 10.3 % and 23.1 % respectively. In Form XVIII those arrangement configurations that can hardly be classified as a definite pattern are grouped together (Fig. 26). The percentage of occurrence of these configuration amounts to 17.9.

TABLE V

The case of 7 chromosomes.

Form	XV 	XVI 	XVII 	XVIII Interm. and irregular	Total
Number of occurrence	4	19	9	7	39
Percentage	10.3	48.7	23.1	17.9	100

The results obtained from the case of 5 chromosomes are shown in Table VI. Here we see that Form XX is of much more frequent occurrence than the other two Forms, XIX and XX, their percentages of occurrence being 59.1 in the former, and 22.7 and 18 2 respectively in the latter two. In the former all the 5 chromosomes form a ring having none inside it (Figs. 27 and 28), and in one of the latter (Form XIX) 4 chromosomes take up their positions on the circumference of

a ring surrounding the fifth (Fig. 29). Form XXI comprises intermediate and irregular configurations that are hardly classifiable as forms of a definite pattern (Fig. 30).

TABLE VI

The case of 5 chromosomes.

Form	XIX 	XX 	XXI Interm. and irregular	Total
Number of occurrence	10	26	8	44
Percentage	22.7	59.1	18.2	100

In the results mentioned above, it is shown that in each case, whether of 5, 6 or 7 chromosomes, the arrangement configuration which occurs most frequently is always that resembling the stable form of arrangement of MAYER's floating magnets, if the chromosome arrangement is examined with respect to the point of spindle fiber insertion in the chromosomes.

CONCLUSION AND SUMMARY

In the heterotype anaphase the configuration of chromosome arrangement, which resembles the stable configuration of MAYER's floating magnets, is of most frequent occurrence in any case where the chromosome number is 5, 6 or 7, and in the homotype metaphase the same is also true, if we consider in the examination only the points of spindle fiber attachment of the chromosomes. The first maximum of the frequency of occurrence is greater in the heterotype anaphase than in the homotype metaphase, and the second maximum is found in the form in which the number of inner chromosomes in the arrangement is less than that of the stable form of MAYER's floating

magnets. The very high frequency of occurrence of the transitory forms (Form II) in the heterotype anaphase may be interpreted as due to the fact that in this plant the chromosomes are linked together into a chain in the metaphase and that it is only in the anaphase that they can move freely to take up their proper positions. The relatively small degree of resemblance to the stable form of MAYER's floating magnets in the homotype division may be regarded as due to the fact that in this plant the long chromosomes have to move in a relatively small confined space.

In conclusion, the writer wishes to acknowledge his gratitude to Prof. Y. KUWADA under whose direction this investigation was carried out.

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