ON THE MORPHOLOGY OF THE CHROMOSO GROUP IN BRACHYSTOLA MAGNA.

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The appearance of Boveri's recent remarkable paper[1] on analysis of the nucleus by means of observations on double- tilized eggs has prompted me to make a preliminary commun tion of certain results obtained in a general study of the germ-c of the great "lubber grasshopper," *Brachystola magna.*

As will appear from a glance at the figures given in my for paper[2] upon the same form, the cells of *Brachystola*, like th of many amphibia, selachians and insects and certain of the fl ering plants, exhibit a chromosome group, the members of wh show distinct differences in size. Accordingly, one feature this later study has been a critical examination of large numb of dividing cells (mainly from the testis) in order to determ whether, as has usually been taken for granted, these differe are merely a matter of chance, or whether, in accordance w the view recently expressed by Montgomery,[3] in regard to a tain pair of elements in the nuclei of one of the Hemiptera, ch acteristic size-relations are a constant attribute of the chro somes individually considered. With the aid of camera drawi of the chromosome group in the various cell-generations, I give below a brief account of the evidence which has led m adopt the latter conclusion.

In the first generation of secondary spermatogonia, which the earliest germ-cells I have been able to obtain in *Brachys* certain differences in length and volume are to be seen betw the members of the chromosome group. These cells, as sh in my former paper already referred to (where they are err

[1] Boveri, Th. (1902), "Mehrpolige Mitosen als Mittel zur Analyse des Zellke *Verh. d. Phys. Med. Ges. zu Würzburg*, XXXV.

[2] Sutton, W. S. (1900), "The Spermatogonial Divisions in *Brachystola magn Kans. Univ. Quart.*, Vol. 9.

[3] Montgomery, T. H., Jr. (1901), "A Study of the Chromosomes of the Cells of the Metazoa," *Trans. Amer. Phil. Soc.*, Vol. XX.

ously described as the last generation of primary spermatogonia), lie in the follicle without definite arrangement and are usually much flattened and distorted by mutual pressure and that of the growing spermatocysts between which they lie. For this reason a study of the chromosome series is difficult in this cell-generation, but, fortunately, I have been able to find a few division-figures which permit of an accurate study of the chromosomes. Such a cell as that shown in Fig. 1—a metaphase in polar view—offers the best opportunities. Here it is apparent at a glance that the chromosomes are of a variety of sizes, but yet in general so nicely graded as to form an almost regular series from smallest to largest. A second glance, however, reveals the fact that there is one very prominent break in this graded series, separating the six smaller chromosomes from the remaining larger ones, and a count of the larger group shows it to contain seventeen units, giving as a total the odd number twenty-three.[1] The odd or twenty-third member of the group, as can be plainly seen in the following division, is the accessory chromosome, which on account of its peculiar behavior will be considered separately. There is, therefore, in the ordinary group, the even number, twenty-two. More especially in the smaller group, but likewise in the members of the sixteen, it can be seen that the gradations in volume are not between individual chomosomes but between pairs, the two members of which in each case are of approximately equal

FIG. 1.

FIG. 1. Polar view of metaphase of first generation of secondary spermatogonia. Six small chromosomes designated by letters *i*, *j* and *k*. (From section.) *Note.*—All figures given in this paper are camera lucida copies of the portions under consideration from the original camera drawings to be published in the forthcoming work to which this is preliminary. The figures are not schematized.

[1] Montgomery (*l. c.*) has found four of the Hemiptera-heteroptera to possess an odd somatic number of chromosomes and I have observed the same to be true for some fifty species of Acrididæ and Tryxalinæ.

size. In other words, there are, in the ordinary chromosome group, not twenty-two but eleven sizes of chromosomes. The lettering in the figure will indicate the pairs in the smaller group where they are most clearly defined.

Eight[1] generations of spermatogonia follow this one, and in each succeeding metaphase the same number and size-relations of chromosomes may be observed. This is shown in Figs. 2 and 3, representing different secondary spermatogonial generations

FIG. 2. FIG 3.

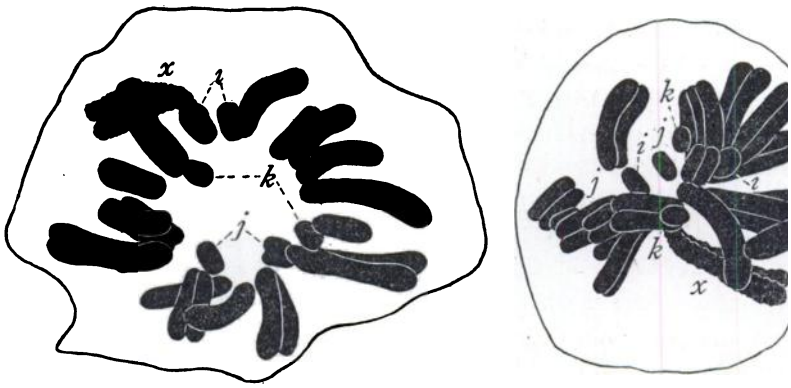

FIG. 2. Polar view of equatorial plate in secondary spermatogonium of one of the earlier generations. (From section.)

FIG. 3. Oblique lateral view of equatorial plate of a secondary spermatogonium of one of the later generations. (From a smear-preparation.) Small chromosomes and accessory designated as in Fig. 1.

in each of which appears six small chromosomes and seventeen larger ones. In each of these also — especially in the case of the smaller group, the members of which, on account of their nearly spherical form, do not suffer the same degree of foreshortening in the drawing as do many of their longer comrades — the paired relation may again be made out. Moreover, in the smaller group with its fewer members and greater size-differences it is possible to see that the volume of the smallest pair (*kk*), for instance, in one cell bears approximately the same ratio to the homologous pair in another cell as does that of the largest (*jj*) of the

[1] Based on estimates of the number of cells in a spermatocyst at the time of transformation to spermatocytes.

first cell to the largest of the second, or the middle-sized pair (*ii*) of the one to the middle-sized pair of the other. In these cells the compact condition of the chromosomes will not permit of the accurate recognition of individual elements — other than perhaps the largest and the smallest — in the group of sixteen, where size differences are comparatively slight, but this deficiency will be made up in the consideration of the group in the spermatocytes.

Throughout all the secondary spermatogonial generations, in all stages except those of active division, the accessory chromosome remains apart in a vesicle which is virtually a separate nucleus. The genetic relation of the accessory chromosome of any secondary spermatogonium to that of any other in its line of ancestry seems, therefore, unquestionable. Each of the sixteen chromosomes of the larger group has also been enclosed in a separate vesicle (Fig. 4) during the period of metabolic activity,

FIG. 4.

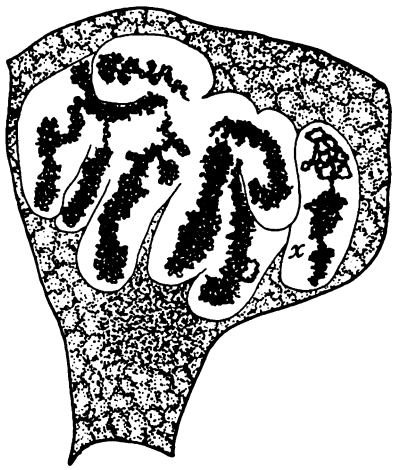

FIG. 4. Secondary spermatogonium in early prophase, showing very fine spiremes arranged in their respective diverticula of the nucleus. Most of the partition walls between diverticula are shorter in the figures than in the preparation, since their crossing if drawn in full would only cause confusion in a line drawing. (From a section.)

but these vesicles are practically always in communication with one another at their polar extremities, forming there a common compartment in which the six smaller units are frequently found.

In this case there is plainly a possibility for an exchange chromatic matter; but since each generation exhibits the sa series of chromosomes as that before; and since, after the sta of the very fine spireme, the chromosomes reappear one in e sacculation as before, no other conclusion seems credible tl that they are, chromosome for chromosome, the same in generation as in another, just as is the case with the accessory

During the transformation to spermatocytes, the nucleus a whole becomes spherical, but, in many cases, the compartme still remain; and in them the chromosomes pass through fine spireme stages. In this condition, as in that just descri for the spermatogonia, it is difficult to conceive the formatio a continuous spireme; but when, at a little later stage, cell nuclear membranes have become less resistant so that their c tents may be smeared upon cover-glasses and there fixed for st *in toto*, it becomes clear that fewer spiremes are present than the spermatogonial nuclei. In every case, the accessory ch mosome appears in its peculiar characteristic condition (x, F 5 *a*, 5 *b*, 6 and 7), and careful counting of a large number of ca *shows the spiremes in every favorable instance to number ele* These spiremes are graded as to size just as were the chro some-pairs of the spermatogonia; and the gap in the series s arates a group of *eight large* from a group of *three small* eleme In most of the spiremes a longitudinal split is clearly visible, in addition, in practically every case, a division may be no separating the spireme into two distinct limbs of approximat equal size, which are frequently doubled on each other at point of union.

If now we seek the relation of these spiremes to the chro somes of the spermatogonia, we find abundant data. Twe two chromosomes enclosed in separate compartments, each op ing at one end into a common chamber, are represented by ele double chromosomes. Scarcely any two of the eleven are e approximately of the same size, whereas each of the twenty-t appeared to have a mate of like volume. But the eleven dou chromosomes are made up each of two limbs of equal size we find it difficult to believe that these limbs do not repres the members of the pairs, joined together at their polar en

FIG. 5a. FIG. 5b.

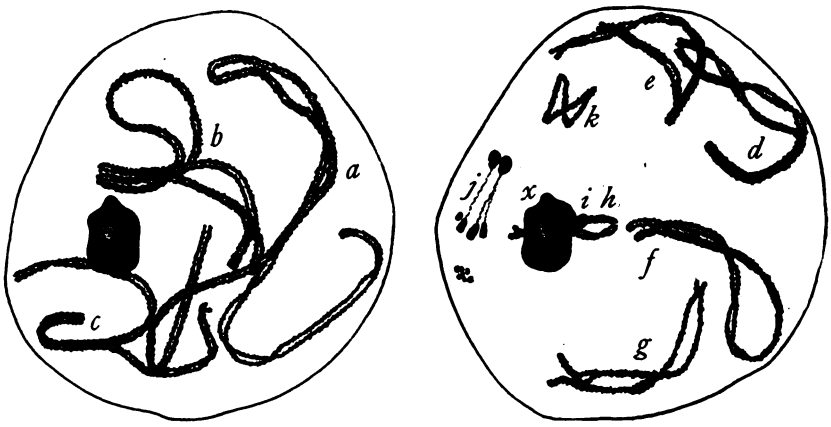

FIG. 5a. Three largest spiremes and accessory chromosome from a primary spermatocyte in early prophase. (Smear-preparation.)

FIG. 5b. Eight remaining chromosomes and accessory from same cell as Fig. 5a.

FIG. 6. FIG. 7.

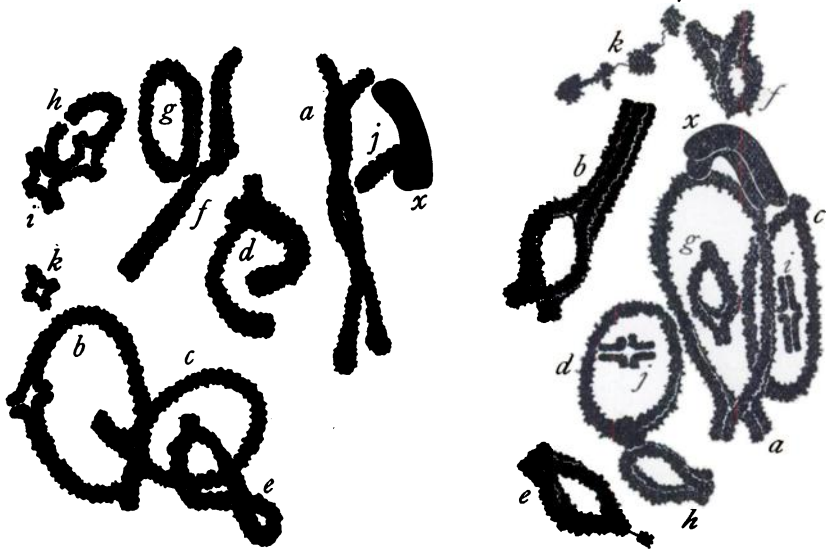

FIG. 6. Partly condensed spiremes in middle prophase of primary spermatocyte. All the chromosomes, including the accessory (x), show indications of a longitudinal split.

FIG. 7. Slightly more advanced chromosome group than that of Fig. 6. Letters a, b, c, d, e, f, g, h, i, j and k designate the different chromosomes in order of size from largest to smallest; x designates the accessory.

which, as we have seen, projected into a common chamber of nucleus. To such a conclusion additional weight is added the occasional finding of telophases of the last spermatogoi generation which actually shows such a fusion (Fig. 8).

FIG. 8.

FIG. 8. Telophase of secondary spermatogonium of the last generation show synapsis. Only a few of the chromosomes are shown and as in Fig. 4; to avoid fusion the sacculations are drawn only to the point where they cross one another.

The four parts of each spireme, marked off by the longitudi split and the line of fusion, may be traced through all the p phases up to the metaphase, where they are clearly seen become the four parts of the tetrad. These facts seem to me leave no escape from the conclusion that in the completed tet the longitudinal split represents merely the usual division o chromosome into equivalent chromatids; but *the transverse ma ing separates two spermatogonial chromosomes which have con gated end-to-end in synapsis.*[1]

Notwithstanding the fact that no continuous spireme is form the various spiremes of the larger group (16 in spermatogonia in spermatocytes) in any nucleus are at any given period alw of approximately the same diameter and the same degree of c centration. Their respective lengths may therefore be taken a measure of their respective volumes, and accordingly the lon

[1] Cf. Montgomery, T. H., Jr. (1901), "The Spermatogenesis of *Peripatus* (*P patopsis*) *Balfouri* up to the Formation of the Spermatid," *Zool. Jahrb.*, XV.; "A Study of the Chromosomes of the Germ Cells of the Metazoa," *Trans. Am Phil. Soc.*, Vol. XX.

and more slender the spiremes, the more pronounced their differences of volume would appear. Obviously, it is impossible to study the length of convoluted spiremes in sections. Smear-preparations also fail in the spermatogonia on account of the strength of the nuclear membrane, which in these cells resists the roughest treatment and prevents the separation of its contained spiremes. But in the prophases of the primary spermatocytes the nuclear membrane becomes so thin and weak that its contents may be readily smeared upon a cover-glass and the spiremes thus separated and to a certain extent flattened in the plane of the cover. In the most favorable of these cases, such as those shown in Figs. 5, 6 and 7, which represent different stages in the concentration of the spermatocyte spiremes, a more or less accurate comparison by means of measurements is possible. For the sake of convenience in reference, we will designate the chromosomes in these figures by the first eleven letters of the alphabet, beginning with the longest chromosome and proceeding according to size. The chromosomes as drawn are in all cases simple projections and hence suffer a greater or less amount of foreshortening according to the degree of their curvature or inclination to the plane of the slide. This, however, is so slight that it has been disregarded in the table except in case of chromosomes *b* and *h* of Fig. 6. In these cases, the actual length in the figure is given in parentheses and an estimate of the real length in the regular column. No attempt was made to measure the three smaller elements, as their variations in form and diameter in the spermatocytes render measurement in one

	Fig. 5.	Fig. 6.	Fig. 7.
a	43	22	21
b	$32\frac{1}{2}$	$19\frac{1}{2}(17)$	17
c	23	$15\frac{1}{2}$	15
d	20	14	12
e	$17\frac{1}{2}$	$12\frac{1}{2}$	9
f	$16\frac{1}{2}$	$10\frac{2}{3}$	$7\frac{2}{3}$
g	15	9	$7\frac{1}{2}$
h	$(7\frac{1}{2})$	$8\frac{1}{2}(7\frac{2}{3})$	7
i			
j			
k			

NOTE. — The figures are in terms of an arbitrary unit equivalent to the distance apart of the divider-points used in making the measurements.

dimension of no value whatever. Naturally these figures ca make no pretensions to complete accuracy but as approximatio they serve to show a uniformity in the different nuclei that cann justly be ascribed to chance. It is worthy of note that the on case in which a chromosome does not bear approximately tl same ratio as its mates to the homologous members of the oth two series is chromosome *h* of Fig. 5; which being hidden f the most part behind the accessory, is at best a doubtful quantit

When the ordinary chromosomes divide in the first mitos of the spermatocytes, the separation takes place along the li of the longitudinal split and therefore, except that the chrom somes are joined together by pairs, differs in no respect from a ordinary spermatogonial division. The accessory chromosom however, though showing a clearly-defined longitudinal spl *does not divide but passes entire to one pole*, as Sinéty [1] has ind pendently observed in the Phasmidæ; and after completion the division may be clearly seen in one only of the two daught cells, where it is sharply contrasted with the partially disintegrat ordinary chromosomes.

FIG. 9.

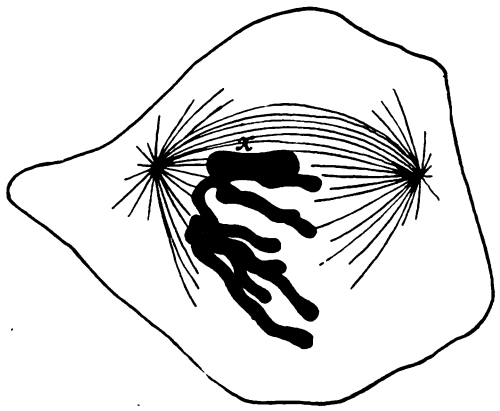

Fig. 9. Four ordinary chromosomes and accessory from a very late prophase the secondary spermatocyte division. Each ordinary chromosome is made up of t limbs connected at one end. There is no longitudinal split.

In the prophases of the second division the chromosomes r appear in the same number and show the same size relation as

[1] Sinéty, R. de (1901), "Recherches sur la biologie et l'Anatomie des Phasmes *La Cel'ule*, T. XIX.

the preceding telophase, but instead of exhibiting a longitudinal split *they are seen to be composed of two equal limbs joined together at one end only* (Fig. 9) *just as when they passed to the pole in the previous anaphases.* The division occurs at the point of junction of the two limbs and is unquestionably transverse — *separating the two chromosomes at the point where they fused in synapsis two generations before.*

In those secondary spermatocytes in which the accessory chromosome occurs, this element also divides, but in the line of the longitudinal split which has persisted from the prophases of the primary generation. One half of the resulting spermatids, therefore, are characterized by the presence of the accessory and the other half by its absence, but this constitutes the only morphological difference between the two categories. In each, the ordinary chromosomes may be seen to constitute a graded series of eleven members in which a considerable gap at one point separates a subgroup of three small units from another sub-

FIG. 10. FIG. 11.

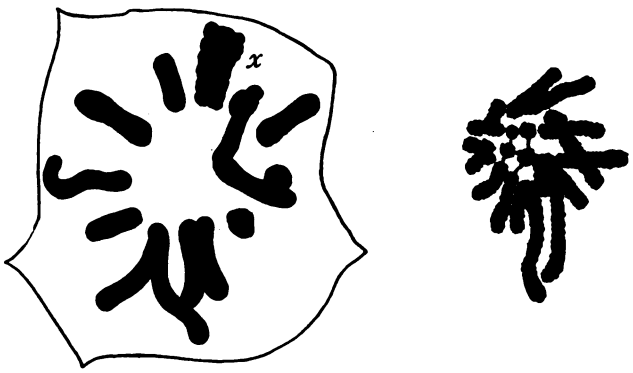

FIG. 10. Polar view of chromosome group in metaphase of secondary spermatocyte containing the accessory chromosome. Eight large and three small ordinary chromosomes appear. (From section.)

FIG. 11. Axial view of chromosome group of ovarian follicle-cell in telophase. Twenty-two chromosomes appear of which six are decidedly small and the other sixteen decidedly larger.

group of eight larger ones (Fig. 10). The series therefore represent exactly half of the ordinary chromosome group as we found it throughout the secondary spermatogonia. This is the chro-

mosome series which forms the chromatic portion of the sp head and consequently is to be regarded *a priori* as the s which will reappear in the sperm-nucleus in the act of fertiliz If this is true — and everything speaks for and nothing defi against the correctness of the assumption — then the concl seems unavoidable that the mate to each of the eleven chr somes must be furnished by the egg-nucleus to produce the e pairs characteristic of all the early germ-cells, of the follicle of the ovary as shown by Fig. 11, and probably also o ordinary somatic cells.[1]

To sum up, in *Brachystola* the nuclei, not only of the synaptic germ-cells, but also of cells which have been shunt from the germinal cycle, are characterized by the possessior chromosome group made up of two morphologically equiv series of eleven members each.[2] Comparison shows tha size-relations between various members of these series ar proximately the same in different nuclei of the same or diff cell generations. The numerical reduction (pseudo-reducti accomplished by the union of homologous members of the series of a nucleus, and this union is terminated in the se spermatocyte division by the separation of the daughter-chr somes of the original conjoints at their point of union and passage to opposite poles. We are virtually able to reco each chromosome in eleven consecutive cell-generations; a the prophases and telophases of nine of these, the chromos are separated from one another for a great part of their le only their polar ends lying in the common chamber. No tinuous spireme is formed; and although after each division is a brief interval, during which chromosomic boundaries c longer be traced, the regular correspondence, unit for unit, mother series with the daughter series establishes a high p bility that we are dealing with morphologically distinct indivi each of which bears to its mother element a genetic re

[1] Cases of cells other than germ-cells in which an accurate count of the c somes is possible are extremely rare on account of the crowded condition c nuclei; but I am able to state that in the cells of the ovarian follicles and of th mon collecting ducts of the testes every division figure shows large and chromosomes in apparently the same relation as those found in the spermatogo

[2] Besides the accessory chromosome.

comparable to that existing between mother- and daughter-cells.

I have endeavored to show that the eleven ordinary chromosomes which enter the nucleus of each spermatid are selected one from each of the eleven pairs which made up the double series of the spermatogonia. It now becomes a highly interesting question whether there exists in the ripe egg a graded series of chromosomes similar to that of the mature male element. I have found the chromosome group not only of the oögonia but also of the ovarian follicle cells (Fig. 11) to correspond perfectly with that of the spermatogonia; and if we are permitted to assume that the reduction process in both sexes is the same, we have no alternative but to believe that the chromosome series of the mature germinal products also are alike. Obviously, copulation of such nuclei in fertilization would restore the conditions which we have found not only in the early germ-cells but in some outside the line of succession.

These latter observations have totally disregarded the accessory chromosome, but it is in it, if further research shall substantiate my present limited but thoroughly consistent results, that we shall find our most unequivocal evidence of chromosomic individuality. We have noted that the spermatogonia have twenty-three chromosomes, and that the odd one of these is the accessory which by means of its idiosyncrasies may readily be recognized in all except the active mitotic stages. We have also noticed that this element is unequally distributed in the maturation divisions and as a consequence occurs in exactly half the spermatozoa. In the oögonia and ovarian follicle-cells in which I have been able to count the chromosomes, I have found but twenty-two; and the fact that none of these behaves in the characteristic manner of the accessory proclaims it the missing member.

We should expect therefore to find but one kind of mature ova in respect to number of chromosomes while we know that by the same standard there are two kinds of spermatozoa. Obviously, then, the number of chromosomes in the cleavage-nucleus of the fertilized egg (twenty-two or twenty-three) must depend upon the number introduced in the sperm-nucleus, since the latter contains either eleven or twelve, according as the accessory chromo-

some is absent or present. Now twenty-three is the numb chromosomes in the male cells, while twenty-two is the nu I have found in the female cells, and thus we seem to f confirmation of McClung's [1] suggestion that the accessory c mosome is in some way concerned in the determination of s

Without discussing here the logical consequences of su conclusion, I will only emphasize the fact that one of the chr somes, which in the primary spermatogonia [2] is scarcely d guishable from its fellows, maintains throughout a long seri divisions an indubitable independence; and finally compl establishes its right to the title of a distinct individual by pa entire to one daughter-cell with the result that no accessory mosome appears in the products of the next division of the c

Taken as a whole, the evidence presented by the cel *Brachystola* is such as to lend great weight to the conclusior a chromosome may exist only by virtue of direct descer longitudinal division from a preëxisting chromosome and the members of the daughter group bear to one another the respective relations as did those of the mother group — in words, that the chromosome in *Brachystola* is a distinct mo logical individual.

This conclusion inevitably raises the question whether th also a physiological individuality, *i. e.*, whether the chromos represent respectively different series or groups of qualiti whether there are merely different-sized aggregations of the material and, therefore, qualitatively alike.

On this question my observations do not furnish direct evic But it is *a priori* improbable that the constant morphologic ferences we have seen should exist except by virtue of fundamental differences of which they are an expression; further, by the unequal distribution of the accessory chromc we are enabled to compare the developmental possibilities o containing it with those of cells which do not. Grantin normal constitution of the female cells examined and the sim of the reduction process in the two sexes, such a comp

[1] McClung, C. E., "Notes in the Accessory Chromosome," *Anal. Anz.* "The Accessory Chromosome, Sex-determinant," BIOL. BULL., III.

[2] A study of the chromosomes of the primary spermatogonia has been r *Melanoplus differentialis*, a nearly related form in which the later divisions ar tially the same as in *Brachystola*.

must show that this particular chromosome does possess a power not inherent in any of the others — the power of impressing on the containing cell the stamp of maleness, in accordance with McClung's hypothesis.

The evidence advanced in the case of the ordinary chromosomes is obviously more in the nature of suggestion than of proof, but it is offered in this connection as a morphological complement to the beautiful experimental researches of Boveri[1] already referred to. In this paper Boveri shows how he has artificially accomplished for the various chromosomes of the sea-urchin, the same result that nature is constantly giving us in the case of the accessory chromosome of the Orthoptera. He has been able to produce and to study the development of blastomeres lacking certain of the chromosomes of the normal series.[2]

In larvæ resulting from double-fertilized eggs which have divided into three cells at the first cleavage, he recognizes an organism made up of definite thirds, each traceable to one of the original blastomeres and each characterized, as a result of the primary hap-hazard tripolar division, by a different combination and generally by a different number of chromosomes from that of its fellows. In rare instances such an embryo may be normal, of which fact the possibility that each pole of the triaster may receive a complete normal series of chromosomes is explanation enough. In other cases, the embryo may be completely normal (for instance in respect to skeleton or pigmentation) in one or two thirds, while in the remaining portion these structures may be entirely lacking; and it is a most significant fact that "in einzelnen dieser Fälle konnte aus der Kerngrösse nachgewiesen werden, dass die Grenze wo der Defekt beginnt, mit der Grenze zweier auf verschiedene Ausgangsblastomeren zurückführender Bereiche zusammenfällt." In the "normal" embryos mentioned above, every part was present, and as regards specific characters, normal; but in different thirds there could be seen individual variations which normally should have appeared in different larvæ. "In der

[1] Boveri, *l. c.*

[2] By the normal series is here meant such a one as occurs in the nucleus of either of the mature germinal products, since it has been clearly shown by the well-known work on the fertilization of enucleate egg-fragments and on chemically induced parthenogenesis, that either of the ripe germ-products possesses all the chromatin necessary for the production of a normal larva.

That," says Boveri, " könnte ich aus den verschiedenen Typen normalen Kontrolzuchten, durch Kombination der rechten Hä einer Larve mit der linken einer anderen, Bilder herstellen, den in Rede stehenden Dreierplutei fast genau entsprech To these points is added the fact that while all the isolated b tomeres of a normal four-cell stage develop exactly alike, tl of dispermic three- or four-cell stages rarely or never do so, e when the numerical distribution of chromosomes appears eq and, further, that in large numbers of larvæ from double-fertil eggs all possible combinations of characters are to be found, as all possible combinations of chromosomes from the three pa cells may enter into the composition of their nuclei. From t and other data, Boveri draws the conclusion that " Nicht eine stimmte Zahl sondern eine bestimmte Kombination von Chro somen zur normalen Entwicklung notwendig ist, und di bedeutet nichts anders als dass die einzeln Chromosomen schiedenen Qualitäten besitzen müssen."

Thus we are brought to recognize a physiological individu in a form in which the chromosomes are morphologically ir tinguishable and the nuclei of which, after the anaphases, offe mechanical hindrance to the free intermixture of the chrom We have already reviewed the reasons for believing the acces chromosome in the cells of *Brachystola* to be the possess specific functions and it only remains again to call attention t likelihood that the constant morphological differences betwee ordinary chromosomes are the visible expression of physiolo or qualitative differences.

In conclusion, from the point of view thus suggested, le again consider the phenomena of fertilization. In either sp or egg-nucleus a complete series must be present since e may produce a normal embryo without the other. Every no fertilized egg, therefore, as well as every cleavage-cell de from it, must have the field of each character covered by chromosomes — one from each parent. The chromosome s of the echinoderm cleavage-nucleus is thus shown to be p ologically a double one just as in *Brachystola* we have seen be morphologically double, and the doubling in both cas seen to be accomplished in an exactly similar way — viz., b contribution of equivalent series by the two parents.

If, as the facts in *Brachystola* so strongly suggest, the chromosomes are persistent individuals in the sense that each bears a genetic relation to one only of the previous generation, the probability must be accepted that each represents the same qualities as its parent element. A given relative size may therefore be taken as characteristic of the physical basis of a certain definite set of qualities. But each element of the chromosome series of the spermatozoon has a morphological counterpart in that of the mature egg and from this it follows that the two cover the same field in development. When the two copulate, therefore, in synapsis [1] the entire chromatin basis of a certain set of qualities inherited from the two parents is localized for the first and only time in a single continuous chromatin mass; and when in the second spermatocyte division, the two parts are again separated, one goes entire to each pole contributing to the daughter-cells the corresponding group of qualities from the paternal or the maternal stock as the case may be.

There is, therefore, in *Brachystola* no qualitative division of chromosomes but only a separation of the two members of a pair which, while coexisting in a single nucleus, may be regarded as jointly controlling certain restricted portions of the development of the individual. By the light of this conception we are enabled to see an explanation of that hitherto problematical process, synapsis, in the provision which it makes that the two chromosomes representing the same specific characters shall in no case enter the nucleus of a single spermatid or mature egg.

I may finally call attention to the probability that the association of paternal and maternal chromosomes in pairs and their subsequent separation during the reducing division as indicated above may constitute the physical basis of the Mendelian law of heredity. To this subject I hope soon to return in another place.

I take pleasure in expressing here my gratitude to Prof. E. B. Wilson for much valuable advice and assistance in the work upon *Brachystola* and in the preparation of the present paper.

ZOÖLOGICAL LABORATORY, COLUMBIA UNIVERSITY,
October 17, 1902.

[1] The suggestion that maternal chromosomes unite with paternal ones in synapsis was first made by Montgomery (1901, I.).