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OF

# CALVIN BLACKMAN BRIDGES

1889–1938

BY

T. H. MORGAN

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Calvin Blackman Bridges was born in Schuyler Falls, New York, on January 11, 1889, and died in Los Angeles, December 27, 1938. His father, Leonard Victor Bridges, who was brought up on a small farm near Plattsburg, married Charlotte Amelia Blackman in 1887, and Calvin was their only child.

His mother died when Calvin was two years old. His father died a year later. The Grandmother Bridges had already brought up a large family but considered it her duty to take charge of Calvin. He went to a small district school when it was convenient. When he was about 14 years old his grandmother insisted that he should be "educated," and he was allowed to go to Plattsburg. He was not ready for high school and had to spend two preliminary years in grammar school. He graduated from high school in 1909 when he was 20 years old. He had made a fine record. During the years at Plattsburg he drove to school part of the time with neighbors and worked and lived much of the time in town. He worked as "printer's devil" on the Plattsburg Press, and it was said "there is a boy who is going to amount to something." When he had spare time he was always at his books, but he was a "regular boy," good-natured and obliging.

One summer during his high school years he worked on a geological survey of Valcour Island with Professor George H. Hudson of the Plattsburg Normal School. There is extant a letter by Professor Hudson written when Calvin applied for a scholarship at Columbia University in which he says: "He is in many respects a very remarkable young man. He has always kept on the honor roll of his school and yet read very extensively outside of the lines of his school work." The list of the books he read, in Calvin's handwriting, exists and it certainly covers a very wide range of subjects. Hudson also says: "He has the questioning mind, is apt in the forming of hypotheses and quick to see when they are weak. His great desire is to undertake research work."

At the end of his high school work Calvin was urged to try the regional examination for a four year scholarship at Cornell which he passed. He also took an examination for a one year scholarship at Columbia University and passed this also. Wishing to live near his aunt, Mrs. Billings, who lived in New Jersey, he accepted the Columbia scholarship. During his three years at college he received some aid from scholarships, but earned much of his living in other ways. During one of the summers he tutored two young boys and during another he went "on the road" to sell a book entitled "Standard Dictionary of Facts."

My first contact with Bridges was in 1909 when he took a course I gave in general biology and another in embryology (1910); and later, as a graduate student, a course in experimental zoology, largely devoted to genetics, and another course in experimental embryology. He attended also Professor E. B. Wilson's course on The Cell.

Bridges graduated (B.S.) from Columbia College in 1912. In the same year he married Gertrude F. Ives, and was survived by his wife and three children, Philip, Betsey and Nathan. From 1910 to 1915 he served as part-time assistant in my work on Drosophila. In the course of this work (Morgan and Bridges 1913) certain exceptions turned up that Bridges began to study intensively. In 1913 he published briefly his results under the title of "Non-Disjunction of the Sex Chromosomes of Drosophila". A much more extended paper appeared in 1916 entitled "Non-Disjunction as Proof of the Chromosome Theory of Heredity". This work, offered as his doctoral dissertation at Columbia University, included not only genetic evidence but corresponding evidence from a study of the chromosomes that tallied with the genetic results. This paper went far towards convincing skeptics and conservatives that chromosomes are the bearers of genetic factors. It is true there was abundant evidence before 1916 showing that chromosome behavior furnishes an interpretation of heredity. It is today hard to believe that it was nearly ten years before this relation was generally accepted.

Sex-linked inheritance, as connecting genetic interpretation with known transmission of the sex chromosomes, had been established since 1910. The interpretation of crossing over, supported by less certain cytological evidence, had also been advanced in 1910, and covered what seemed to be exceptions to Mendel's laws. Crossing over opened up a new field of research in inheritance, and for 30 years formed the basis on which much of Bridges' work rested. He greatly improved the technique of locating the genes, and in the course of the following years he so thoroughly built up the genetic maps that these stand today as the most complete data we have on the location of the genes in the chromosomes.

In 1915 I received a grant from the Carnegie Institution of Washington to carry on investigations in heredity. Bridges and Sturtevant were appointed to undertake independent research work. For twelve years we three worked together in a small room in the Zoological Department of Columbia University. As the work on Drosophila ampelophila (as the vinegar fly was then called) became widely known, a succession of international fellows joined us, as well as some of the more advanced graduate students and fellows of Columbia University. It was not unusual for six of us to carry on in this small room; the only space at our disposal. Those were the days when bananas were used as fly food and in one corner of the room a bunch of bananas was generally on hand—an adjunct to our researches which interested other members of the laboratory in a different way. As there were no incubators, a bookcase and a wall case were rigged up with electric bulbs and a cheap thermostat, which behaved badly at times, with consequent loss of cultures. The use of milk bottles came into the program at an early date, but where they came from was not known, or at least not mentioned. At a later date we were bold enough to ask for a case of new bottles.

This picture of the conditions under which we worked is not intended to suggest that we were handicapped. On the contrary, our proximity to each other led to cooperation in everything that went on. The discovery of a new mutant was immediately announced, and its location in the gene chain anxiously awaited.

The Carnegie group worked at Columbia University until 1928, and from 1928 to 1938 at the California Institute of Technology. The annual grants from the Carnegie Institution of Washington contributed greatly towards the success of the genetic work on Drosophila.

The improvements that have gradually evolved have been to a large extent the outcome of Bridges' unusual inventive faculty. The hand lens was replaced by a binocular microscope of his designing; the wall cases have been supplemented by incubators with fans and expensive regulators; the banana has given place to a synthetic medium consisting of agar agar, corn-meal, molasses, and yeast. Even the symbols by which the Drosophila mutant races were named are in large part attributable to Bridges' interest in a suitable nomenclature. I recall one instance in which invention went too far. In order to save space in the incubators Bridges drew a plan for a milk bottle with a square base. But they were so closely packed that when the room temperature approached the lethal degree, the heat generated in the bottles went over the top. Unwilling to give up the new bottles Bridges got a large auger and bored holes through the carefully prepared insulated walls of the incubator.

Bridges had his own system of bookkeeping. The data were often filed on bits of scrap paper, but it was almost uncanny to see how quickly he could find any information that was called for. He has left hundreds of cards, carefully filed, which contain all the data collected in this laboratory relating to each mutant or aberration. Many of these data have never been published, and it is doubtful now if anyone will ever assemble them for publication. These data were used, however, in the calculation of loci and description of mutants and aberrations, in DIS 9, which appeared shortly after Bridges' death. This issue of Drosophila Information Service was one of the last things on which Bridges worked, and in it, fortunately, he brought down to date practically all his work in statistical genetics.

In 1916 Bridges and I brought together the then known data on the mutants and linkage relations of the first or X chromosome of Drosophila, in 1919 those of the second chromosome were published, and in 1923 we published the data which had accumulated on the third chromosome group of mutants. Later (1935) Bridges gave a complete account up to date of the fourth chromosome (*Journal of Biology,* Moscow, U.S.S.R.).

The first gynandromorph of Drosophila was discovered in 1910. From that time onward such exceptions were watched for and recorded. In time Bridges and I had a considerable number on hand which we described in a Carnegie Publication in 1919. Bridges reported (1939) that we had at that time studied "about 100 gynandromorphs and found that the maternal X was eliminated about as often as the paternal X. In experiments in which all flies were counted 40 gynandromorphs occurred in 88,000 flies." In addition to our explanation of elimination of one of the X chromosomes, during early development, a few other exceptions were found that called for a different explanation; namely, the presence of two separate nuclei and reduction products in the egg.

Later, Bridges discussed a few individuals showing spots on the body which, from genetic evidence, were composed of haploid cells, and, in some of these mosaics, the regions included body parts that enabled one to diagnose their sex. The spots were clearly female in constitution, and this was surprising at the time since in other insects, where haploid individuals were known (bees, etc.), they were males. Bridges' finding in Drosophila was, however, consistent with the female sex formula: two X plus two sets of autosomes. In the spots the same balance is present, that is one X and one set of autosomes, so that the haploid somatic tissue is female.

During the years 1921-1925 Bridges made an extensive study of certain types of intersexes in Drosophila. He showed clearly by cytological analyses that they were due to chromosome aberrations of a type that had not been established previously for intersexes of other insects. The intersexes showed complex mixtures of male and female parts. In the first culture in which they were found (1920) there were 37 of them in addition to 9 regular males and 96 females. They were completely sterile, but certain of their sisters, when bred, gave intersexes and were shown by genetic and cytological evidence to be triploid (3N) females. The breeding experiments with such females showed that a certain proportion of their mature eggs contained one full set of chromosomes, one X and one of each autosome, and, in addition, part or all of one extra set. Those mature eggs that contained a diploid set of chromosomes, would, if fertilized by a normal X-bearing sperm, again give 3N females, and if fertilized by a Y sperm would give intersexes. The formula for the intersexes is $3A + 2X + Y$. They differ from standard females only in having an extra set of autosomes, and this fact, as Bridges points out, "proved that autosomes (A) are as much determiners of the normal sex differences as are the so-called sex chromosomes. Autosomes turn the scale toward maleness." This idea of genic balance he had already developed in 1921 in connection with changes induced by loss or gain of a fourth chromosome. The theory was applied to the interpretation of certain other abnormal-appearing types of individuals, notably superfemales and supermales. A superfemale, he showed, arises when an individual has three X chromosomes and two autosomes. A supermale arises when one X and three sets of autosomes are present. Three types of females may exist in which the balance between X's and autosomes is the same as in the normal ($2X + 2A$) female, namely $3X + 3A$ and $4X + 4A$, besides the normal. These conclusions of Bridges were not theoretical speculations, but in every case the interpretation rested on genetic evidence, and in triploids and diploids on a cytological demonstration of the presence in the individual in question of the constellation of the chromosomes that was postulated.

Bridges paid a great deal of attention to the problem of genic balance, pointing out that it is fundamental for an understanding not only of the balance concerning sex, but for all other characters as well. The fact is that today there is demonstrable evidence that there is not a single gene for femaleness and another for maleness, but several, perhaps many, genes distributed through the chromosomes and affecting the development of certain characters in one way or in the opposite way. This conception in its broadest aspects has always been insisted on by the group working on the genetics of Drosophila, although it is also true that a change in a single gene often leads to striking changes in the individuals containing such a mutant gene. They argued that both the old and the new gene influence the end result, not by acting alone but by collaborating with other genes, and, in the last analysis, with all or most of the genes to different degrees. Each gene is thought of as a differential.

Bridges' early discovery (1917) that certain genetic data could be interpreted as due to deficiencies in the chromosome construction has led in recent years to a factual demonstration of such deficiencies. In some of his latest work (1937-1938) he made use of this discovery in the interpretation of overlapping deficiencies in analyzing the characteristics of certain mutant types. It would be hard to find in the history of genetic research a more convincing demonstration of the combination of actual evidence and masterly interpretation of it. As early as 1919 Bridges described "duplication" as a chromosomal aberration, and here, as in his other work, his conclusions rested not on vague hypotheses but on experimental proof. Much later he also reported the occurrence of "repeats" in the normal chromosome which will have to be seriously considered in future interpretations of certain types of genetic behavior.

The many interesting problems connected with losses (deficiencies) and additions (duplications) of groups of genes present interesting problems in which genic balance is involved, and the possibility, that now exists, of detecting deficiencies and duplications in the salivary chromosomes and correlating the observations with the genetic location of mutant genes is well under way, and during the last two years of his life, was receiving Bridges' close attention.

In 1925 the data, that had been collected in the course of genetic experiments, was brought together under the title "The Genetics of Drosophila," by T. H. Morgan, C. B. Bridges, A. H. Sturtevant. Not until 1934, when the first number of Drosophila Information Service edited by Bridges and Demerec appeared, was a similar summary made. Bridges spent a tremendous amount of hard work in summarizing the data, particularly those of the stocks that the Carnegie group had built up at Pasadena, and the reports include also much unpublished data that Bridges himself had on hand. Fourteen numbers of

Drosophila Information Service have appeared, the latest in February 1941.

In recent years Bridges spent much time in correlating the loci of the genetic maps with the bands of the salivary maps. He made an elaborate study of the salivary chromosomes, and more than doubled the previously known number of bands. His maps have become the standard ones for Drosophila melanogaster. As I have pointed out elsewhere, the identification of the salivary bands with the loci on the genetic map would not have been possible were it not that during the preceding twenty-three years the genetic (crossover) maps had been built up to a point where such comparisons have a real demonstrable basis. While many workers had contributed to bring the genetic maps to their status of 1933, it was Bridges in particular who had made a more detailed and critical study of the maps than had any other one of his contemporaries. His maps are now standard all over the world. During the year 1938, Bridges continued the revision of the maps of the salivary chromosomes; that of the X-chromosome has been published in the Journal of Heredity, January 1938. During the summer of 1938 he nearly finished the right half of the second chromosome in collaboration with his son Philip, who has now put it into shape for publication. He intended to leave the left half of that chromosome until the revision had extended to the other chromosomes because he had found that this half probably contains a number of "repeats", i.e., sections of duplicating parts. This idea is the last of the many new contributions that Bridges made to the "higher Mendelism" and may prove of unusual interest in the future development of genetics.

The original discovery of the banded nature of the giant salivary chromosomes of diptera goes back to Balbiani's record of 1881. But the regularity of the sequences of the bands, the union of homologous chromosomes in pairs, and distinction of regions that stain and those that do not stain was reported in 1933 by Heitz and Bauer.

Painter, also in 1933, using Drosophila melanogaster material, contributed the all-important proof that there is a close correspondence between the sequence of the banding of the chromosome and the sequence of the genes as determined by genetic theory and practice. Without the already existing information as to the position of the genes in definite chromosomes it would have been impossible to establish this relationship, although Painter and Muller had already in 1929 laid the basis for comparisons of this kind by demonstrating that certain genetic translocations could be visibly detected as such in the chromosomes involved in such transfers.

It became increasingly important after Painter's comparisons between the genetic and the salivary maps that identification of the bands be extended to the limit of microscopic vision in order to determine more definitely the relation of individual bands to the loci of the genes, since the determination of the correspondence between the sequence of the genes and that of the bands does not tell us whether there is an identity between them. Most of the bands are faint ones while some of the darker bands are double, etc. For this kind of work Bridges was eminently fitted. His eyesight was unusually acute but he did not depend on this alone and spent much time in the study of the best methods of illumination, and the most suitable staining and preserving technique to bring out the fainter bands. As a result his new maps more than double the number of the previously known visible bands. He was also interested in the problem as to whether the stretching of the chromosome, when the nucleus is burst under pressure, may introduce artifacts. It is unfortunate that he died when in the midst of this detective work, but his methods will enable others to take up the story where he left off.

As a member of the Carnegie group each year's progress was reported in the Year Book of the Carnegie Institution of Washington. These twenty-three reports give in briefest summary the results that Bridges had obtained. Whether the elaborate data on which these reports rested, can ever be fully utilized is questionable; but Bridges accomplished so much other work, that these will not be needed to place him amongst the leading geneticists of his time.

Bridges was a very friendly person. He was simple and unaffected and always helpful to anyone who came to him for advice. In the course of twenty years he was largely instrumental in building up stocks of Drosophila in which mutant genes of each chromosome are spaced so that they can be used as markers for each chromosome. These stocks are especially useful in studying crossing over, translocation and other special problems. More than 900 separate stocks are carried at present. Many of them have been distributed to investigators all over the world. Bridges spent much thought and time in building up this material and distributed it freely without even claiming credit from others for its use. In fact, one of his most admirable traits was his freedom from priority claims of any kind. His death was a serious loss to genetics and to his many friends.

## BIBLIOGRAPHY

### KEY TO ABBREVIATIONS

Amer. Nat. = American Naturalist.
Anat. Rec. = Anatomical Record.
Arch. Entw.-mech. = Archiv für Entwicklungsmechanik der Organismen.
Biol. Bull. = Biological Bulletin.
Biol. Zentral. = Biologisches Zentralblatt.
Bull. Inst. Gen. = Bulletin, Institute of Genetics, Academy of Sciences, U. S. S. R.
Carnegie Inst. Wash. Publ. = Carnegie Institution of Washington, Publications.
Carnegie Inst. Wash. Yr. Book = Carnegie Institution of Washington, Year Book.
Jour. Biol. (Moscow) = Journal of Biology (Moscow).
Jour. Exp. Zoöl. = Journal of Experimental Zoölogy.
Jour. Franklin Inst. = Journal of Franklin Institute.
Jour. Gen. Physiol. = Journal of General Physiology.
Jour. Heredity = Journal of Heredity.
Peking Nat. Hist. Bull. = Peking Natural History Bulletin.
Proc. Birth Con. Cong. = Proceedings, Birth Control Congress.
Proc. Nat. Acad. Sci. = Proceedings, National Academy of Sciences.
Proc. 6th Int. Cong. Genetics = Proceedings, Sixth International Congress of Genetics.
Proc. Soc. Exp. Biol. Med. = Proceedings of the Society for Experimental Biology and Medicine.
Trans. Dyn. Develop. = Transactions on the Dynamics of Development.
Zeit. Abst. Vererb. = Zeitschrift für Induktive Abstammungs und Vererbungslehre.

*1913*

Partial sex-linkage in the pigeon. *Science*, n. s. **37**: 112-113.

Non-disjunction of the sex chromosomes of Drosophila. *Jour. Exp. Zoöl.*, **15**: 587-606.

Dilution effects and bicorlorism in certain eye colors of Drosophila. (With T. H. Morgan.) *Jour. Exp. Zoöl.*, **15**: 429-466.

*1914*

Direct proof through non-disjunction that the sex-linked genes of Drosophila are borne by the X-chromosome. *Science*, n. s. **40**: 107-109.

The chromosome hypothesis of linkage applied to cases in sweet peas and primula. *Amer. Nat.*, **48**: 524-534.

A new gene in the second chromosome of Drosophila and some considerations on differential viability. (With A. H. Sturtevant.) *Biol. Bull.*, **26**: 205-212.

*1915*

A linkage variation in Drosophila. *Jour. Exp. Zoöl.,* **19**: 1-21.

The Mechanism of Mendelian Heredity. (With T. H. Morgan, A. H. Sturtevant, and H. J. Muller.) New York, 262 pp.

*1916*

Non-disjunction as proof of the chromosome theory of heredity. *Genetics,* **1**: 1-52, 107-163.

Sex-linked inheritance in Drosophila. (With T. H. Morgan.) *Carnegie Inst. Wash. Publ.,* **237**: 87 pp.

*1917*

The elimination of males in alternate generations of sex-controlled lines. *Anat. Rec.,* **11**: 504.

An intrinsic difficulty for the variable force hypothesis of crossing over. *Amer. Nat.,* **51**: 370-373.

Deficiency. *Genetics,* **2**: 445-465.

Incompatibility of mutant races in Drosophila. (With C. W. Metz.) *Proc. Nat. Acad. Sci.,* **3**: 673-678.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and A. H. Sturtevant.) *Carnegie Inst. Wash. Yr. Bk.,* **15**: 343.

*1918*

Maroon—a recurrent mutation in Drosophila. *Proc. Nat. Acad. Sci.,* **4**: 316-318.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and A. H. Sturtevant.) *Carnegie Inst. Wash. Yr. Bk.,* **16**: 290-291.

*1919*

Duplication. *Anat. Rec.,* **15**: 357.

The genetics of purple eye color in Drosophila melanogaster. *Jour. Exp. Zoöl.,* **28**: 265-305.

Specific modifiers of eosin eye color in Drosophila melanogaster. *Jour. Exp. Zoöl.,* **28**: 337-384.

Vermilion-deficiency. *Jour. Gen. Physiol.,* **1**: 645-656.

The developmental stages at which mutations occur in the germ tract. *Proc. Soc. Exp. Biol. Med.,* **17**: 1-2.

The inheritance of the mutant character "vortex". (With O. L. Mohr.) *Genetics,* **4**: 283-306.

The second-chromosome group of mutant characters. (With T. H. Morgan.) *Carnegie Inst. Wash. Publ.,* **278**: 123-304.

The origin of gynandromorphs. (With T. H. Morgan.) *Carnegie Inst. Wash. Publ.,* **278**: 1-122.

The construction of chromosome maps. (With T. H. Morgan.) *Proc. Soc. Exp. Biol. Med.*, **16**: 96-97.

The inheritance of a fluctuating character. (With T. H. Morgan.) *Jour. Gen. Physiol.*, **1**: 639-643.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and A. H. Sturtevant.) *Carnegie Inst. Wash. Yr. Bk.*, **17**: 277-278.

The spatial relations of genes. (With A. H. Sturtevant and T. H. Morgan.) *Proc. Nat. Acad. Sci.*, **5**: 168-173.

*1920*

White-ocelli—an example of a "slight" mutant character with normal variability. *Biol. Bull.*, **38**: 231-236.

The mutant crossveinless in Drosophila melanogaster. *Proc. Nat. Acad. Sci.*, **6**: 660-663.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and A. H. Sturtevant.) *Carnegie Inst. Wash. Yr. Bk.*, **18**: 324-325.

The evidence for the linear order of the genes. (With T. H. Morgan and A. H. Sturtevant.) *Proc. Nat. Acad. Sci.*, **6**: 162-164.

*1921*

Gametic and observed ratios in Drosophila. *Amer. Nat.*, **55**: 52-61.

Proof of non-disjunction for the fourth chromosome of Drosophila melanogaster. *Science*, n. s. **53**: 308.

Current maps of the location of the mutant genes of Drosophila melanogaster. *Proc. Nat. Acad. Sci.*, **7**: 127-132.

Genetical and cytological proof of non-disjunction of the fourth chromosome of Drosophila melanogaster. *Proc. Nat. Acad. Sci.*, **7**: 186-192.

Triploid intersexes in Drosophila melanogaster. *Science*, n. s. **54**: 252-254.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and A. H. Sturtevant.) *Carnegie Inst. Wash. Yr. Bk.*, **19**: 329-331.

*1922*

The origin of variations in sexual and sex-limited characters. *Amer. Nat.*, **56**: 51-63.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and A. H. Sturtevant.) *Carnegie Inst. Wash. Yr. Bk.*, **20**: 375-380.

*1923*

The translocation of a section of chromosome II upon chromosome III in Drosophila. *Anat. Rec.*, **24**: 426-427.

Aberrations in chromosomal materials. Eugenics, Genetics, and the Family. **1**: 76-81.

The third-chromosome group of mutant characters of Drosophila melanogaster. (With T. H. Morgan.) *Carnegie Inst. Wash. Publ.,* **327:** 251 pp.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and A. H. Sturtevant.) *Carnegie Inst. Wash. Yr. Bk.,* **21:** 325-328.

The Mechanism of Mendelian Heredity. Revised Edition. (With T. H. Morgan, A. H. Sturtevant and H. J. Muller.) New York, 357 pp.

Laboratory Directions for an Elementary Course in Genetics. (With T. H. Morgan, A. H. Sturtevant, and H. J. Muller.) New York, 16 pp.

*1924*

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and A. H. Sturtevant.) *Carnegie Inst. Wash. Yr. Bk.,* **22:** 283-287.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and A. H. Sturtevant.) *Carnegie Inst. Wash. Yr. Bk.,* **23:** 231-236.

*1925*

Sex in relation to chromosomes and genes. *Amer. Nat.,* **59:** 127-137.

Elimination of chromosomes due to a mutant (Minute-n) in Drosophila melanogaster. *Proc. Nat. Acad. Sci.,* **11:** 701-706.

Haploidy in Drosophila melanogaster. *Proc. Nat. Acad. Sci.,* **11:** 706-710.

Crossing over in the X-chromosomes of triploid females of Drosophila melanogaster. (With E. G. Anderson.) *Genetics,* **10:** 418-441.

The Genetics of Drosophila. (With T. H. Morgan and A. H. Sturtevant.) *Biblographia Genetica,* **2:** 1-262.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and A. H. Sturtevant.) *Carnegie Inst. Wash. Yr. Bk.,* **24:** 286-288.

*1926*

The mechanism of sex-determination. *Proc. Birth Con. Cong.,* New York. p. 10.

Genetics of Sciara. Rep. of paper by C. W. Metz. "The Collecting Net," Woods Hole, Mass., **1:** 7.

The multiple stock 'Xple' and its use. (With T. M. Olbrycht.) *Genetics,* **11:** 41-56.

The linkage relations of a benign Tumor in Drosophila. (With M. B. Stark.) *Genetics,* **11:** 249-266.

The mutants of the extreme left end of the second chromosome of Drosophila melanogaster. (With C. Stern.) *Genetics,* **11:** 503-530.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and A. H. Sturtevant.) *Carnegie Inst. Wash. Yr. Bk.,* **25:** 312-315.

*1927*

The relation of the age of the female to crossing over in the third chromosome of Drosophila melanogaster. *Jour. Gen. Physiol.*, **8**: 689-700.

Constrictions in the chromosomes of Drosophila melanogaster. *Biol. Zentral.*, **47**: 600-603.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and A. H. Sturtevant.) *Carnegie Inst. Wash. Yr. Bk.*, **26**: 284-288.

*1928*

The chromosomes of Drosophila melanogaster. "The Collecting Net," Woods Hole, Mass., **3**: 10-11.

The behavior of mutable genes. Review. *Ibid.* **3**: 10.

Chromosome aberrations and the improvement of animal forms. *Jour. Heredity,* **19**: 349-354.

Some physicochemical aspects of life, mutation and evolution. (With Jerome Alexander.) *Anat. Rec.*, **41**: 96.

Some physicochemical aspects of life, mutation and evolution. (With J. Alexander.) Colloid Chemistry; Vol. II; Biology and Medicine. Chemical Catalogue Co., pp. 9-58.

The reproductive system of triploid intersexes in Drosophila melanogaster. (With Th. Dobzhansky.) *Amer. Nat.*, **62**: 425-434.

The giant mutation in Drosophila melanogaster: Part I; the heredity of giant. (With E. Gabritschevsky.) *Zeit. Abst. Vererb.*, **46**: 231-248.

The giant mutation in Drosophila melanogaster: Part II; Physiological aspects of the giant race; the giant 'caste'. (With E. Gabritschevsky.) *Zeit. Abst. Vererb.*, **46**: 248-284.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and A. H. Sturtevant.) *Carnegie Inst. Wash. Yr. Bk.*, **27**: 330-335.

*1929*

Variation in crossing over in relation to age of female in Drosophila melanogaster. *Carnegie Inst. Wash. Publ.*, **399**: 63-89.

Deficient regions of Notches in Drosophila melanogaster. (With J. C. Li.) *Ibid.* 91-99.

Some physicochemical aspects of life, mutation and evolution. (With J. Alexander.) *Science,* **70**: 508-510.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and A. H. Sturtevant.) *Carnegie Inst. Wash. Yr. Bk.*, **28**: 338-345.

*1930*

Review of the seminar report of Dr. Huettner. "The Collecting Net," Woods Hole, Mass., **5**: 113-115.

The neutralization of the effects of deficiencies through duplications of the chromosome materials. *Ibid.*, **5**: 273-274.

Haploid Drosophila and the theory of genic balance. *Science,* **72**: 405-406.
The constitution of the germinal material in relation to heredity. (With T. H. Morgan and Jack Schultz.) *Carnegie Inst. Wash. Yr. Bk.,* **29**: 352-359.

*1931*

El tipo mutante "pink-wing" de Drosophila melanogaster. Un problema de localizacion. English summary. "Eos," **7**: 229-248.
The genetic conception of life. Address given before Academy of Science, U. S. S. R., Leningrad.
The constitution of the germinal material in relation to heredity. (With T. H. Morgan and Jack Schultz.) *Carnegie Inst. Wash. Yr. Bk.,* **30**: 408-415.

*1932*

The suppressors of purple. *Zeit. Abst. Vererb.,* **60**: 207-218.
Apparatus and methods for Drosophila culture. *Amer. Nat.,* **66**: 250-273.
Specific suppressors in Drosophila. *Proc. 6th Int. Cong. Genetics,* **2**: 12-14.
The genetics of sex in Drosophila. Sex and Internal Secretions. Baltimore, Chap. III: 55-93.
Recombination and crossing-over. *Amer. Nat.,* **66,** 571-574.
The constitution of the germinal material in relation to heredity. (With T. H. Morgan and Jack Schultz.) *Carnegie Inst. Wash. Yr. Bk.,* **31**: 303-307.
Methods for distinguishing between duplications and specific suppressors. (With Jack Schultz.) *Amer. Nat.,* **66**: 323-334.

*1933*

A system of temperature control. (With Hugh H. Darby.) *Jour. Franklin Inst.,* **215**: 723-730.
Culture media for Drosophila and the pH of media. I. Improvements in culture methods: the role of yeast. (With Hugh H. Darby.) *Amer. Nat.,* **67**: 437-472.
The mutant "proboscipedia" in Drosophila melanogaster—a case of heredity homoösis. (With Th. Dobzhansky.) *Arch. Entw.-mech.,* **127**: 575-590.
Constitution of the germinal material in relation to heredity. (With T. H. Morgan and Jack Schultz.) *Carnegie Inst. Wash. Yr. Bk.,* **32**: 298-302.

*1934*

The test-cross—a suggested genetic term. *Jour. Heredity,* **25**: 18.
A gas-operated incubator for Drosophila cultures. (With J. C. Li.) *Peking Nat. Hist. Bull.,* **8**: 269-272.
Constitution of the germinal material in relation to heredity. (With T. H. Morgan and Jack Schultz.) *Carnegie Inst. Wash. Yr. Bk.,* **33**: 274-280.

*1935*

The mutants and linkage data of chromosome four of Drosophila melanogaster. *Jour. Biol.* (Moscow), **4**: 401-420.

Salivary chromosome maps—with a key to the banding of the chromosomes of Drosophila melanogaster. *Jour. Heredity,* **26**: 60-64.

Cytological data on chromosome four of Drosophila melanogaster. *Trans. Dyn. Develop.,* **10**: 463-473.

The apterous-d mutation in Drosophila melanogaster (Russian, with English summary). (With N. N. Medvedev.) *Bull. Inst. Gen.,* No. **10**: 199-209.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and Jack Schultz.) *Carnegie Inst. Wash. Yr. Bk.,* **34**: 284-291.

*1936*

Genetical and cytological studies of a deficiency (Notopleural) in the second chromosome of Drosophila melanogaster. (With Eleanor Nichols Skoog and J. C. Li.) *Genetics,* **21**: 788-795.

Demonstrations (1) of the first translocations in Drosophila melanogaster and (2) of normal repeats in chromosomes. *Amer. Nat.,* **70**: 41.

The Bar "gene" a duplication. *Science,* **83**: 210-211.

Microscope illumination systems. "The Collecting Net," Woods Hole, Mass., **11**: 208.

An oil-retaining beveled face for high-aperture condensers. *Science,* **84**: 335-336.

Genes and chromosomes. The Teaching Biologist, Nov. 1936.

Progress in cytogenetics. "The Collecting Net," Woods Hole, Mass., **11**: 244-245.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and Jack Schultz.) *Carnegie Inst. Wash. Yr. Bk.,* **35**: 289-297.

*1937*

The vapor method of changing reagents and of dehydration. *Stain Technology,* **12**: 51-52.

Correspondences between linkage maps and salivary chromosome structure, as illustrated in the tip of Chromosome 2R of Drosophila melanogaster. *Cytologia, Fujii Jubilee,* Vol., 745-755.

Revised data on culture media and mutant loci of Drosophila melanogaster. *Tabulae Biologicae,* **14**: 343-353.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and Jack Schultz.) *Carnegie Inst. Wash. Yr. Bk.,* **36**: 298-305.

*1938*

A revised map of the salivary gland X-chromosome of Drosophila melanogaster. *Jour. Heredity,* **29**: 11-13.

The future of genetics. *Current Science,* Special number on "Genetics," Mar. 1938, 37-39.

Salivary analysis of inversion-3R-Payne in the "venation" stock of Drosophila melanogaster. (With P. N. Bridges.) *Genetics,* **23**: 111-114.

Is agglutination an explanation for the occurrence and for the chromomere-to-chromomere specificity of synapsis? (With C. C. Lindegren.) *Science,* **87**: 510-511.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and Jack Schultz.) *Carnegie Inst. Wash. Yr. Bk.,* **37**: 304-309.

*1939*

Cytological and genetic basis of sex. Sex and Internal Secretions. Second edition. Baltimore, Chap. II, 15-63.

A new map of the second chromosome. A revised map of the right limb of the second chromosome of Drosophila melanogaster. (With P. N. Bridges.) *Jour. Heredity* **30**: 475-476.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan, Jack Schultz and Viola S. Curry.) *Carnegie Inst. Wash. Yr. Bk.,* **38**: 273-277.