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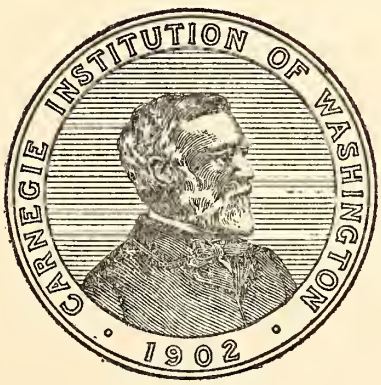

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DEPARTMENT OF GENETICS[1]

C. B. Davenport, Director

GENERAL STATEMENT

It is only a little over a quarter of a century since the obvious importance of Mendelism led, for the first time in the history of science, to a concentrated attack on problems of heredity and variation. As Mendel suspected, and as modern biologists at once demonstrated, his laws were a consequence of inheritance through the germ-cells, which we now recognize have the reduced number of chromosomes. The studies of the first half of this period led to the recognition of the wide applicability of Mendel's laws, but revealed unconformable cases. The studies of the second half of this period brought many of the unconformable cases under the general laws of linkage and crossing over on the one hand, and chromosomal aberrations on the other.

The spiral movement of science brings biology again face to face with the problem of the mechanics of development with which we were concerned 35 years ago, but we view it now from the new standpoint of our knowledge that the chromosomes in some way direct development from the inside. How they do it, we do not yet know. But, obviously, this control is a biochemical process of a refined and complicated sort. The next step in the study of development, as a physiological process, is a study of the biochemical changes involved. This field we can hope to enter, even while we continue to explore the field of the relation of somatic differentiation to chromosomes.

Two developmental phenomena seem especially attractive for analysis, because of their excellent definition. One is sex; the other, growth; and to these phenomena we have paid especial attention. It has seemed possible to control and alter them and thus get an insight into the mechanisms involved in their production. As for sex, the work of the year has confirmed our earlier conclusions that extracts of female plants, at least, have a stronger reducing capacity on the average than the extracts of male plants; and further study may reveal the substances that are chiefly responsible for this difference, whether aromatic compounds, like tannins, reducing sugars or other. Simultaneously it appears that the value of the Manoilov reaction as a test of sex depends on the fact that it is a test of metabolic level, and this differs on the average and in the long run in the two sexes. It has been concluded that the sex ratio in mammals can be altered by the presence of alcohol in the parental blood, but during the year this conclusion has been overthrown by the critical work of MacDowell. Clearly the sex-differential in the protoplasm is chiefly located in the chromosomes. A difference in the proportion of the two sexes during early development, due to conditions external to the fetus, has not yet been shown. Meanwhile Metz has continued his studies that reveal a remarkable mechanism in the egg of a fly (*Sciara*) by which, apparently, it controls the sex of the offspring that shall arise from the fertilized egg, by its control over the chromosomes which direct the development of sex characters.

The attempt to learn the chromosomal mechanism that calls forth males in Daphnids under the influence of protoplasm-depressing agents in the medium

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in which the mother is living has not been wholly successful; probably on account of the great difficulties offered by the behavior and small size of the chromosomes.

Growth is a process that involves the ingestion of materials for metabolism. But the use that shall be made of available materials is determined by the developing organism. The curve of intrauterine growth (in the mouse) has been worked out by MacDowell, with the cooperation of Allen, and he shows that mouse, guinea-pig and chick follow a similar course or law of growth during early stages, after the embryo proper has begun to undergo differentiation. On the other hand, Davenport (with the collaboration of Professor W. W. Swingle) finds that (in the mouse) the growth process may be interfered with (retarded) by cauterizing the thyroid-parathyroid apparatus of the mother. Other experiments have been undertaken to change the velocity of growth at different stages.

Mutation, as the very heart of the problem of evolution, continues to be one of the leading subjects of our research. *Datura* is yielding, slowly, new gene mutations in the different chromosomes; and the presence of the genes helps interpret the numerous irregularities of the chromosomes as a whole. The irregularities, in turn, of these chromosomes lead, in some cases but not in others, to defective pollen. This fact opens up a broad field for research.

The new mutations, both in *Datura* and *Drosophila*, are showing the phenomena of reverse mutation, or mutation to the wild type. And such mutations occur frequently in the development of the soma. Certain types of mutations continue to show their close correlation with visible chromosomal conditions; and the effects of such visible changes on mutation and heredity are being worked out by Belling in many species. He concludes that homologous chromosomes do not generally twist around an imaginary axis running between them, but that there may be link-like unions or temporary fusions at nodes. These observations help to explain crossing over and irregularities of composition of large sections of chromosomes. The different types of chromosomal changes and unions lead to different types of inheritance.

Applications of genetical findings are being made at the Eugenics Record Office. The investigation of inheritance of racing ability in thoroughbreds has developed into a research of considerable magnitude. A comparative study is being made of the physical and mental capacities of negroes, whites and cross-breeds in the Island of Jamaica, British West Indies. An intensive study is being carried out on the families whence successful college athletes have sprung. The inheritance of goiter is being investigated. The conditions under which these researches at the Eugenics Record Office are being undertaken is one of especial interest and significance. All four of those referred to in this paragraph are made possible by gifts from outside sources—two are supported by private individuals who have been desirous of promoting special researches; two are supported by organizations—the Carnegie Foundation for the Advancement of Teaching and the Public Athletic League of Baltimore. In these researches the Institution provides overhead and directs the research. The funds granted are used exclusively in gathering, analyzing and summarizing the data. These researches offer examples of a cooperation that is especially productive in relation to the amount expended. It may be anticipated that more such opportunities for cooperation will arise in the future.

STAFF

The director has been continuing his work on modification of the growth curve of mice by special operations, with particular relation to the bearing of this problem on abnormal human development. He has been surpervising the work on negro-white crosses in Jamaica and investigations on heredity of goiter and of athletic capacity. Dr. A. F. Blakeslee, assistant director of the Station for Experimental Evolution, has continued his work on mutations in *Datura* and their relation to chromosomal irregularities. His work has continued with Miss Satina on bio-chemical differences in the sexes of mucors. Dr. H. H. Laughlin, assistant director of the Eugenics Record Office, has completed his studies on deportation in the United States and on economic-population conditions over the world. He has continued the research on heredity of racing capacity on thoroughbred horses, a research supported by W. J. Salmon. Dr. John Belling has continued his fundamental researches on chromosomal behavior. Dr. A. M. Banta, in collaboration with Dr. Ezra Allen and with the assistance of Miss Thelma Wood and, during the summer, the cooperation of Dr. L. A. Brown, has continued his studies on sexual reproduction in *Cladocera*. He gave a course of lectures at the University of Minnesota during two and a half months. Dr. M. Demerec has continued his work on mutations in *Drosophila* and *Delphinium* with special reference to mutable genes. He has nearly completed his studies on albinism in maize, carried on in cooperation with Dr. R. A. Emerson. Dr. C. W. Metz, assisted by Miss Mildred S. Moses, has made progress in the explanation of the peculiar sex ratios in the offspring of *Sciara*.

In the physiology of development, Dr. E. C. MacDowell and Dr. Ezra Allen have made marked progress in the study of intrauterine deaths in mice and they have completed a study of the prenatal growth curve in mice. Dr. Oscar Riddle is continuing his work on chemical and metabolic distinctions of sex, using especially pigeons and doves. He is continuing his efforts to establish races characterized by large and small endocrine size and is collaborating with Professor F. G. Benedict, with the technical assistance of Miss Edith Banta, in a study of racial metabolism of pigeons of known genetic constitution. He visited Europe during October and November, as delegate to the First International Congress for Sex Research in Berlin, during one of the days of which he presided at a general session.

On the human side, the studies of Dr. Howard J. Banker have been continued on teachers' marks, as a criterion of general and special mental capacity. This study is introductory to a study of inherited mental capacity in school children. Dr. Estabrook is bringing to a close his study of the population at the head waters of the Kentucky River.

The experimental breeding pens of mice have continued in the charge of Miss Elizabeth Lord, whose technical experience has made it possible to work with genetically known and improved strains. The pigeon houses have been in charge of Dr. Riddle and Miss Florence Flemion. The Eugenics Record Office archives have been in charge of Miss Alice Gould since the retirement of Miss Grace Allen in the autumn. The computing room has continued in immediate charge of Miss Catherine Carley, who has put through statistical work for various members of the staff. The greenhouses and gardens have

been in charge of Amos G. Avery. The library has been in charge of Mrs. Laura C. Boulton.

Dr. Ezra Allen, on leave of absence from his college for the year, has collaborated in the study of the chromosomal conditions found in male and female *Cladocera* and also in the embryological work with mice. Warren H. Reinhart collaborated during the summer with Dr. Riddle in the study of the Manoilov reaction. Dr. John T. Buchholz, at that time of the University of Arkansas, collaborated in the *Datura* work.

DETAILED REPORT ON CURRENT INVESTIGATIONS

THE GERM PLASM

Studies on the chromosomes—the mechanism that directs development—have been continued through the year, opening up new lodes of rich material.

Sciara

This genus of flies, whose unique method of maturation has been elucidated by Metz, has been further studied. It has been found that still additional species of the genus show the peculiarities of chromosome behavior previously reported of *Sciara coprophila* and other species.

Last year Metz reported that during the first spermatocyte division the chromosomes of maternal origin separate bodily from their paternal mates and that one of the two groups is regularly cast out of the gamete. Genetic study of one mutant character (truncate) was shown in last year's report to verify this for one chromosome in *Sciara coprophila*. Since it was obviously important to determine whether or not the principle applies generally here, especial emphasis has been put on further breeding work. Several mutant characters have been found, but in only one case has the inheritance been worked out fully enough for a comparison. This case is in another species, *Sciara simulans* Joh., and shows the same type of inheritance as that in *S. coprophila*.

One of the most important points in the *Sciara* work is that the sex of the offspring is determined in some way or other. Cytologically, sex is determined either by the retention of a special pair of chromosomes that comes from the sperm (resulting in a male) or the elimination of these chromosomes, resulting in a female zygote. While in most *Diptera*, sperm are of two types, male-producing and female-producing, in *Sciara* they are all "male-determining," for the female-determining sperm fail to develop. One might, accordingly, expect only male offspring from fertilized eggs; but, as a matter of fact, female offspring are produced as well as males.

The details are full of interest. In some species (e. g. *Sciara coprophila*) particular pairs of flies uniformly give progeny which are all of the same sex or nearly so. When individual females are mated to one male after the other, the progeny are all of the same sex, regardless of the number of males used. When one and the same male is mated to two or more females the total of his offspring may include large numbers of each sex; while one of the females often gives only daughters and the other only sons. The conclusion is that the females are immediately responsible for the sex of the offspring. It accordingly appears that at fertilization the eggs of male-producing females permit

the sex-limited chromosome brought in by the sperms to remain in the fertilized egg. On the contrary, the eggs of the female-producing females presumably exclude the two large sex-limited chromosomes that are brought in by the sperm or extrude those sex-limited chromosomes later. In species that have the ordinary bisexual progeny, presumably each female produces equal numbers of the two types of eggs.

We do not yet know whether sex is influenced directly by the sex-limited chromosome or is primarily dependent on other chromosomes. Part of the above-described process is still hypothetical, as not all of its details have been observed—especially the mechanism by which the two sex-limited chromosomes are excluded from some eggs and not from others remains to be worked out. Enough has been learned, however, to make it clear that, while in other flies the sex is determined by a difference in the chromosomes of the two kinds of sperm, in *Sciara* (the sperms being alike) the determination of sex is a function of the female gametes. Cytological evidence indicates, however, that the male is "potentially heterozygous for sex" and capable of producing two kinds of sperm, but that the female-determining kind of sperm is eliminated in the course of the ripening of the sperm by means of a selective and unequal reduction division. Dr. Metz concludes, therefore, that there can be little doubt that in the ancestors of *Sciara* the males produced the two kinds of sperms and were responsible for "sex determination," as in most other known groups of flies. But in this genus, just on account of the loss of one of the two kinds of sperm, the function of sex determination has been forced upon, or assumed by, the egg. In many of the species of insects, as well as vertebrates, the female gamete alone determines sex. It seems possible, therefore, that in this study of *Sciara* we may learn something of the evolutionary process by which the change from sperm determination to egg determination of sex has been brought about. The Committee for Research on Problems of Sex of the National Research Council is collaborating with us in the study of fertilization and ovogenesis to throw further light upon this problem of sex determination.

Mutable Genes

During the past year Demerec has continued his observations on the topic which he has made his own and which opens the door to new interpretations as to the nature of the gene. These studies have been made, as hitherto, both upon the fly *Drosophila* and the flowering plant *Delphinium.*

MAGENTA EYE COLOR IN DROSOPHILA VIRILIS

During the year under review a new mutating gene has been found in *D. virilis.* It is a sex-linked, recessive eye-color character and is called magenta-*a*. The most important results obtained in the experiments with this gene may be summarized as follows: (1) magenta-*a* is an allelomorph of magenta, which latter character was already known at the time magenta-*a* was found. (2) Magenta-*a* mutates frequently to the wild-type of eye color. That the observed results were due to a change in the gene rather than to chromosomal or other non-gene abnormality was indicated by the genetical behavior of the character, both in crosses between magenta-*a* and magenta; in crosses in which different regions for the sex chromosome were investigated and found to be present by the genes located in these regions and,

finally, by the behavior of magenta-*a* when homozygous. (3) Wild-type flies, obtained as a result of the change of the magenta-*a* gene, bred as constant wild type, indicating that the gene is mutable in one direction. (4) Magenta-*a* behaves like the miniature-*a* wing character described in last year's report and further described below. Thus, it mutates in all stages of development. Mutations were, indeed, observed at the formation of the germ-cells in both heterozygous and homozygous females; in the germ-cells of males and in the somatic cells of both females and males. (5) In the classes of the progeny which originated as a result of reversion of magenta-*a* the amount of crossing-over, as compared with normal crossing-over, was increased in the magenta-forked region and decreased in the miniature-magenta region.

MINIATURE WING CHARACTER IN DROSOPHILA VIRILIS

As already mentioned in last year's report the gene for the wing character known as miniature-*a* mutates frequently to its wild-type allelomorph, and such mutations occur in somatic cells as well as in germ-cells. Somatic mutations produce mosaic individuals, while the mutations affecting the germ-cells give rise to flies of the wild type.

Demerec finds that the frequency of somatic, as well as germinal, mutability can readily be influenced by selection. Thus by selection it was possible to isolate in a material which originated from a single miniature-*a* gene the following lines:

1. An almost constant line which, when bred for 14 generations, produced no wild-type fly out of 8,130 individuals observed. This line gives regularly, however, about 3 per cent of mosaic flies arising from somatic mutations. Thus, in this line, miniature-*a* behaves as constant germinally and slightly mutable somatically.

2. A mosaic line which, in 4 generations, produced 2,480 individuals, all of them mosaics. In this line, then, miniature-*a* behaves as constant germinally and very mutable somatically.

3. A highly mutable line which, in 6 generations, gave a total of 2,487 wild-type, 2,211 mosaic and 1,531 miniature individuals. Thus miniature-*a* of this line is highly mutable, both germinally and somatically.

The question arose what was the cause of the difference between the foregoing lines that were isolated by selection? Did the selection produce the change in the miniature-*a* gene or was something else affected by the selection? Results of intercrosses between different lines give the answer to these questions. It was found that the mosaic line differed from the almost constant line in having a dominant autosomal gene that stimulated the mutability of the miniature-*a* gene in somatic cells but did not affect its mutability in germ-cells. This gene was located in the second chromosome. Similarly, it has been discovered that another dominant autosomal gene stimulates miniature-*a* to mutate in germ-cells but does not affect its somatic mutability. The results of these experiments indicate that the gene for miniature-*a* is in a labile condition. It can be influenced to mutate back to its wild-type allelomorph by at least two other genes. The action of genes that stimulate the mutability of miniature-*a* was found to be limited to a definite period of development, and this period was different for different genes.

ORIGIN OF MUTATIONS AND THEIR MUTABILITY

Magenta-*a* was the fifth new mutant found since the studies on mutable genes in *Drosophila virilis* began. Of the 5, 3, namely reddish-*a*, miniature-*a*, and magenta-*a*, were found to be mutable. Since the studies on mutable reddish-*a* indicated that a mutable gene may become constant and also that, without selection, the frequency of mutability decreases rapidly, it appears probable that there may be a connection between the origin of mutations and mutability. The hypothesis was advanced that the genes are mutable at the time of their origin but, sooner or later, become constant. To detect the mutability of the new mutants, proper tests had to be made soon after their origin and thus their exceptional mutability at that time was discovered. The foregoing hypothesis would conform with the conception that the gene is not an ultimate genetic unit but a complex structure.

Subsequent to the origin of magenta-*a*, however, 4 new mutants have been found—all of them constant, which would not be expected according to the hypothesis. The studies on the mutability of miniature-*a* indicate, however, that the mutability may be highly modified by different factors and the presence of such different factors is a possible reason why the potential mutability of some of the mutants was not detected.

LAVENDER FLOWER COLOR IN DELPHINIUM

During the past year the main problem in the work with *Delphinium ajacis* was the nature of the mutability of the gene for lavender flower-color which frequently mutates back to the dominant allelomorph. In plants homozygous for the lavender gene the flowers have a lavender color and are covered with more or less numerous blue spots. These blue spots are interpreted as due to mutations during the course of somatic development of the gene for lavender color to the gene for blue color. It was shown that these changes may affect the germ-cells, since by self-pollinating blue-spotted lavender plants entirely blue plants were obtained, in addition to spotted lavender plants. Two of these plants were selfed and they gave a total of 18 blue progenies and no lavender plant.

An examination of the size of the blue spots on the lavender plants showed that they are prevailingly of two types; small dots and large regions covering several flowers. Medium-size spots were very rare. The size of the spots may be taken as an indication of the time when mutation occurs—small spots occurring late in development and large spots occurring early. By the method of measuring the size of the spots which was described in last year's report (pages 35 and 36) the mutability of the gene for lavender was determined for 6 cell-generations toward the end of the development of flowers. Expressed in percentages it was found to be 2.6, 2.7, 3.3, 5.5, 12.8 and 73.1 in the first and to the sixth cell-generation respectively. It will be noted from these results that the mutability of the lavender gene was low and almost constant in the first three cell-generations for which the measurements were made. In the fourth generation the frequency doubled; in the fifth generation it increased 5 times, and in the sixth the increase was 28 times. The increase of mutability toward the end of development was so high, that 89.5 per cent of all mutations that occurred during the development occurred in the last stages of that development.

The mutability of this lavender gene was found to be high, also, in the early stages of the development of the plants. This was evident from the number of large blue sectors, involving several flowers of the raceme. Of 80 plants that were examined, 13 were chimeras with blue sectors covering one-tenth to one-half of the plants; 42 showed blue sectors that were larger than half the plant, and only 25 were without blue flowers. It is concluded that the germ-cells are probably formed when the mutability of the gene is high because of the fact that self-pollinated lavender plants with small spots gave 116 blue and 74 spotted lavender offspring. The almost entire absence of medium blue spots on the lavender plants indicates that the mutability of the lavender gene is low during the middle period of development. The gene for lavender color, consequently, mutates differently in different stages of the development of the plant. It has a high mutability in the early stages of development; a low one in the middle stages and a very high one toward the end of development.

Datura

The studies in the mutations of the germ-plasm of *Datura* and the phænotypical conditions associated with such germ-plasmic mutations have been made by Dr. Blakeslee, in charge, associated with Dr. Belling and with the assistance of Amos G. Avery, Associate in Plant Breeding, Miss Nancy D. Crockett, assistant, and, during the summer, of Professor John T. Buchholz, Miss Louise Buck, Mr. J. L. Cartledge, Miss Rachel Hynes and Miss Betty Watt.

NEW GENES

The discovery of new gene mutations in *Datura* is of the highest importance, inasmuch as it serves to reveal the chromosome whose tripling is responsible for each 2n+1 mutant found in this species. These genes are recognized by their Mendelian behavior. The new genes have been located in the proper chromosome by the method of trisomic ratios. Of especial interest is the recessive character tricarpel (tc) which has been located in the Reduced (R) chromosome. Dr. Blakeslee reports on these new genes—

"Of plants heterozygous for tricarpel, the female back-crosses give normal 1 : 1 ratios but the male back-crosses (using pollen from the heterozygote) give ratios of about 5 dominants to 1 recessive. An investigation by Dr. Buchholz of the pollen-tube behavior has shown that tubes which carry the gene tc generally swell up and burst before reaching the ovary so that in a mixed population of normal and tricarpel pollen tubes, those carrying the gene for tricarpel are seldom able to function. This developmental selection which takes place in the growth of pollen tubes tends to eliminate the new character.

"A factor for pale leaves has been located in the Globe chromosome, one for short stature in the Elongate chromosome, and one for the white flower-color found in *Datura ferox* in the Glossy chromosome.

"The gene for *ferox* white and for the dominant character Bronze are of some interest. They are both in the Glossy chromosome and apparently allelomorphic to each other. Bronze can show only on purple plants but the gene for ferox white suppresses the expression of the Bronze character in purple plants heterozygous for both Bronze and ferox white."

REVERSE MUTATION

As Demerec has found in *Drosophila* that reddish and miniature-*a* mutate back to normal, so reverse mutations have been found by Blakeslee in *Datura*.

"The mutant swollen (sw) has shown irregularities in its inheritance but the breeding evidence has seemed to indicate that the gene sw is located in the Ilex chromosome. This year we combined swollen with several other genes, thus making up double recessives to be used as testers. Offspring from an F_1 from the cross $p_2\ Sw_2 \times P_2\ sw_2$ segregated for P and p but threw no swollens. The matter has been tested further. We now have several cases in which the seeds from one capsule of a heterozygous plant threw offspring segregating for swollen, but the seeds from another capsule of the same plant failed to produce them. In two of these cases, the parent was a simplex heterozygous Ilex and threw Ilex offspring in the usual proportion even from the capsule from which no swollens were produced. If the gene for swollen is, in fact, located in the Ilex chromosome, the preceding shows that the peculiar behavior is not due to chromosome elimination. It appears to be due, rather, to a reverse mutation of the recessive gene sw to its dominant allelomorph Sw, taking place somatically in a heterozygous individual. Swollen has not thus reverted in the homozygous condition."

INHERITANCE IN SECONDARIES

As shown in the earlier reports, the secondaries in *Datura* represent primaries in which the extra chromosome has a modified constitution. Blakeslee reports on the results of investigating the inheritance of genes that have been located—

"from a single primary (2n+1) type. It has been customary to investigate its inheritance in the secondaries of this type. The genes for white (p) and curled (c) have been located in the Poinsettia chromosome. Dwarf, the secondary of Poinsettia, when heterozygous for P throws disomic ratios but, when simplex for c, throws in female back-crosses an approach to the trisomic ratios 2 C : 1 c among the normal offspring and throws only C's among the dwarf offspring. The duplex heterozygous Dwarfs throw offspring, among which all the normals are c and all the Dwarfs are C. We have not yet been able to get a homozygous curled Dwarf as we could easily have done if the double-half chromosome were not carrying C. The simplex Dwarf may be written $\frac{P}{C}\ \frac{P}{c}\ \frac{C}{C}$, in which the dotted lines separate the chromosome halves and the last fraction represents the double half chromosome. Similarly the duplex Dwarf would be $\frac{P}{c}\ \frac{P}{c}\ \frac{C}{C}$. From the results just given, it has been concluded that the Dwarf half of the Poinsettia chromosome carries the locus for c, while the other half contains the locus for p. There are at least three types of chromosomal behavior that might account for trisomic instead of the disomic inheritance to be expected from simplex Dwarfs. (1) Crossing-over between the $\frac{C}{C}$ chromosome and the $\frac{P}{c}$ chromosome. This appears unlikely since no C normals appear from duplex Dwarfs. (2) Detachment of the $\frac{P}{c}$ chromosome. Somatic elimination of the c chromosome was reported last year for two simplex Poinsettias and one simplex Dwarf. Records this past year from sectorial branches on two simplex and one duplex Poinsettias show again that in each case a c and not a C chromosome was eliminated and

suggest that the gene for curled has been responsible in some way for these somatic eliminations of the chromosome in which it is located. (3) Selective disjunction producing more $\frac{P}{C}$ gametes than $\frac{P}{c}$ gametes. The question is being investigated further.

"Maple is another secondary which behaves like Dwarf in that it has given trisomic ratios when simplex for either Bronze or ferox white, the genes for which are located in the Glossy chromosome. Maple is peculiar in that it appears to show morphological resemblance to both the primaries Buckling and Glossy. It has been preliminarily classed as a secondary of Buckling, however, because it had thrown a relatively high proportion of this primary in its offspring and in many characters appeared to be complementary to Strawberry which is a secondary of Buckling. The possibility is being kept in mind that the Maple half of the Glossy chromosome may contain a portion of the Buckling chromosome."

BAD POLLEN INDUCERS

In the last report evidence was presented for the existence of bad pollen inducers that when crossed with our Line 1, as a standard, gave in F_1 50 per cent aborted pollen grain ovules. Further studies have been made upon this subject and upon this activity Dr. Blakeslee reports as follows:

"Trisomic ratios in back-crosses indicated that both the Echinus and the Microcarpic chromosomes were responsible for the Line 7 pollen type. The testing of our collection of biotypes for bad pollen inducers has been continued. In the last tabulation there were 85 lines which were of the same pollen type as Line 1, since the F_1's with Line 1 had good pollen, and 15 lines of the same type as Line 7, since their F_1's with Line 7 had good pollen and their F_1's with Line 1 had 50 per cent bad pollen. In addition there were a half-dozen lines, the F_1's of which with both Line 1 and Line 7 showed definite percentages of bad grains. One of these, collected in Angol, Chile, produced F_1's with Line 1 which showed 25 per cent bad grains. The ratios of plants with good and with 25 per cent bad grains in the back-crosses indicated that the cause of the aborted grains was located in the Globe and in the Cocklebur chromosomes. Furthermore, the production of bad grains was linked with the factor for pale leaves shown to be in the Globe chromosome. This cross has given rise to several new types related to Cocklebur and Globe. By *inter se* crosses and by trisomic ratios in respect to plants with good and with definite proportions of bad grains, it is hoped to be able to establish a classification of the pollen types in our collection and to learn what pairs of non-homologous chromosomes have been responsible for each type. In addition to our main lines, we have a considerable number of extractives from the cross between Line 1, *Datura stramonium*, and *D. ferox*, the F_1's between which and Line 1 give various percentages of bad grains. It is hoped we may be able to discover by bad pollen induction and trisomic ratios what are the differences between the chromosomes in two species in nature.

"The hypothesis of segmental interchange between non-homologous chromosomes suggested by Dr. Belling for the origin of the B whites is being used for the explanation of the bad pollen inducers. Miss Haynes and Miss Buck last summer found in the F_1's between B whites and Line 1 closed rings of four attached chromosomes which would be expected on this hypothesis, but in F_1's between Line 1 and the Line 7 type of bad pollen inducers no such attachment of four chromosomes. The question is being investigated why F_1's with B whites do not produce bad pollen and why F_1's

with Line 7 type bad pollen inducers do not produce closed rings of four chromosomes. A tentative hypothesis has been formed suggesting that in the origin of B whites the chromosomal parts had been interchanged in such a way that the ends were kept free and repulsion at disjunction in F_1's might therefore be expected to produce only Line 1 and B white type pollen grains without non-viable combinations whereas, in the origin of Line 7 type bad pollen inducers, two of the parts interchanged had their ends reversed so that no opportunity for four attachments would be possible and with random assortment of chromosomes taking place, non-viable combinations in the pollen grains might be expected. We are studying the chromosome configurations in F_1's between Line 1 and a considerable number of lines of diverse origin. So far, Miss Bergner has found one case in which there are 10 sets of two and a string of four chromosomes which do not form a closed ring. For this reason and because the largest chromosome does not seem to be in the string of four, it seems probable we are dealing with interchange between two homologous chromosomes different from these involved in the origin of B whites. The open configuration of four chromosomes might be accounted for if only one of the parts interchanged had been reversed."

SECTORIAL CHIMERAS

Mention has been made above of 2n branches produced on Poinsettia plants by the elimination of a chromosome which carried the gene for curled. Dr. Blakeslee reports upon certain chimeras as follows:

"Last fall a plant, somewhat resembling Poinsettia, was discovered to have its stem streaked with green, suggesting the elimination of the chromosome carrying the gene for purple from the heterozygous condition. Ultimately the green streaks involved a bud, and a green-stemmed branch with white flowers resulted, which has bred true for white. The purple branch has produced a number of green streaked seedlings from selfing in addition to showing segregation for purple and whites. It is of interest that from male back-crosses from the purple branch we have obtained two seedlings with green streaks indicating that the cause of the streaking can be transmitted through the pollen.

"Green streaking on otherwise purple stems has occurred in a considerable number of seedlings from capsules injected with chloral hydrate. The plants treated were recessive whites and following treatment were pollinated from dominant purples. Back-crosses of flowers on these green sectors to whites have produced mostly white seedlings but also a few purples indicating that these sectors were perhaps mixochimera.

"The haploid (1n) plant which we have kept growing by grafts has given rise to two different types of branches. It has not yet been possible to get chromosomal counts from both, but judging from the small proportion of aborted pollen grains and from the large size of the capsules, one is diploid or modified diploid. The other is perhaps a recessive somatic mutation since Miss Bergner has found the normal 1n number of chromosomes in its pollen mother-cells."

Chromosome Behavior in Various Species of Flowering Plants

Dr. John Belling has continued his study of the behavior of chromosomes in the early metaphase stage—a study which directs attention to the remarkable forces that are operating in determining such behavior. We have, how-

ever, at present, no insight into the nature of these forces. Belling reports as follows:

CHIASMAS, TWISTS AND FUSIONS OF HOMOLOGOUS CHROMOSOMES

In *Lilium*, especially, the so-called "strepsinema" stage, or the stage at which the paired chromosomes twist more or less tightly one about the other, is well developed for microscopical observation. *Lilium longiflorum* has a haploid (or reduced) group of 12 chromosomes which are not of very different length but vary in form from a J-chromosome with constrictions well removed from the ends, passing through forms (I-chromosomes) in which the constriction approaches nearer the ends, and, in the other end of the series, chromosomes in which the constriction is, doubtless, terminal. The strepsinema stage is shown in all 12 paired chromosomes (bivalents). This strepsinema stage has been figured by authors as if all the nodes were twists. To make sure of this point requires the best possible fixation and critical microscopy. These nodes in *Lilium* may perhaps be: (*1*) chiasmas; (*2*) half twists; (*3*) temporary fusions of the two homologs; or (*4*) nearly all alternate openings between random pairs of chromatids. Belling finds that over half of them are chiasmas and that demonstrable half twists are scarce in *Lilium longiflorum* and *L. regale*. In the *Lilium* where the relations between the chromosomes are clearer than in most plants the strepsinema stage comes from that which immediately precedes by an opening-out between the members of the pairs of chromosomes; that is, presumably, by repulsion between the homologues. The nodes are already present in the preceding stage and the change and repulsion of the chromosomes in the strepsinema stage make the nodes more evident. In passing from the strepsinema stage to the following stages nearly half of the nodes disappear and there are left only the chiasmas. The nodes that disappear are either half twists or temporary fusions, possibly mostly the latter. In *Lilium* nearly 40 nodes were counted at the strepsinema stage, but only a few over 20 were left in the following stages (in the late prophase or in the metaphase).

Chiasmas may be regarded as demonstrated for many of the nodes in *Uvularia*, *Hyacinthus* and *Lilium*. The hypothesis that the nodes are due to alternate openings between random pairs of chromatids is probably negatived by the following considerations: (a) if the 4 chromatids open out, or repel, equally there should be a large number of cases of the 3 : 1 or 1 : 2 : 1, or 1 : 1 : 1 : 1 assortments, which do not occur; (b) many of the cases with one node (forming crosses) should have the same assortment on both sides of the node, and hence should show no chiasma; a phenomenon which does not seem to occur; (c) with heteromorphic homologues, half of the early crosses should show separation between the two halves of the homologue; which does not seem to have been seen; (d) in *Lilium* and *Tulipa* (as described by Newton) there are intermediate nodes between the chiasmas, as already stated above, and these would interfere with the regular alternation of opposite "openings-out"; (e) in the triploid *Hyacinthus*, combinations of the ring and cross, for example, occur; and these can not be made to fit the opening-out hypothesis.

The objections that Belling finds to considering the nodes as half-twists are the following: (a) many of them (60 per cent in *Lilium*) are visibly chiasmas; (b) the origin of regular twists would require the revolution of one homologue about another for which no probable cause appears; (c) the disappearance of nearly half of these nodes in *Lilium* (as in Tulipa) would require counter revolutions, which are unlikely.

The criteria of a chiasma are several: (a) there is visible a distinct X, plus two parallel chromatids on opposite sides; (b) the two diverging homologues on each side of a node are at right angles; (c) the vertical halves of rings or

V's separate at the metaphase without splitting apart, while the horizontal V's split; (d) the two chromatids of one branch of a V or ring diverge after passing the node.

NODES OF BIVALENTS IN LILIUM

In the earliest prophase (immediately following the strepsinema stage) 39 nodes were counted in the 12 bivalents in *Lilium longiflorum*. In the latest prophase *Lilium* averaged 23 nodes. In the metaphase the count was 23 nodes. Thus about 16 nodes disappeared between early and late prophase. Belling regards it as possible that these 16 nodes were merely temporary fusion points between the two homologues.

NODES OF BIVALENTS IN HYACINTHUS

In *Hyacinthus* the bivalents are clumped and granular at the early prophase. At the latest prophase and in the metaphase the nodes were counted in 116 bivalents. Of these 62 had one node and 54 had two nodes. In other cases bivalents with three nodes have been seen but not here. When from these chiasmas the percentages of crossing-over of genes that should result were calculated, the figures were of the same order as the results with chromosome I in *Drosophila melanogaster*.

DIPLOID AND TRIPLOID HYACINTHUS

The comparison of bivalents and trivalents in *Hyacinthus* has been resumed. The conclusion reached is that the three homologues conjugate with one another, just as the two homologues do in a bivalent. This applies to large, medium and small bivalents. The resulting configurations are usually complicated because of the varying position and number of the nodes.

CHAINS OF CHROMOSOMES IN RHOEO

"There are apparently three main kinds of inheritance at present known; gametic inheritance, worked out chiefly by De Vries and Renner in varieties and species of *Oenothera;* chromosomal inheritance, discovered first by Mendel, in varieties or species of *Pisum*, and including diploid, triploid and tetraploid inheritance; and chromomeral inheritance, investigated mainly at Columbia University in species of *Drosophila*. In Belling's opinion gametic inheritance has now at last been shown, especially by Cleland (1922 to 1925) and Håkansson (1926), to depend on the formation of a complete or partial chain (or ring) of chromosomes before the first metaphase.

"In *Rhoeo discolor*, a not uncommon greenhouse plant, there are twelve chromosomes (one can not apparently say six pairs), and all twelve are regularly arranged in a chain at diakinesis and the first metaphase in the maturation divisions. Bivalents are not seen. Alternate chromosomes often pass to opposite poles, as Cleland found in *Oenothera*. The formation of pollen tetrads is usually normal.

"The results in Mendelian terminology are somewhat as if the plant had only two chromosomes, apparently without crossing-over, and was a permanent heterozygote; both homozygotes perishing, or one class of gametes perishing as pollen and the other as embryo sacs.

"This mode of inheritance, whose cytological basis has now been found in both monocotyledons and dicotyledons, will probably not be common, because half of the gametes or zygotes must die if the line is to be constant. However, it affords facilities for the production of permanent heterozygotes by the crossing of varieties, subspecies and species. F_1 plants would usually be constant, and reciprocal crosses would differ (as happens more or less in the

Oenotheras, some of which, however, show mixed gametic and chromosomal inheritance, having incomplete rings or chains). Any of these permanent heterozygotes might become relatively constant and diploid by doubling its chromosome group. This, which in true diploid plants would result in a true tetraploid, would here produce a more or less irregular 'double diploid', which would not show tetraploid (tetrasomic) inheritance of genes.

"Since the first plant found with n extra chromosomes was an *Oenothera*, it has been taken as a sample of triploids. A *Rhoeo* with a group of six extra chromosomes will not be a true triploid, since it has only six pairs of true homologues; and the six other chromosomes can not be called homologues, if only because their terminal attractions differ. Hence the 'semigigas' *Oenothera biennis*, or a possible similar variation in *Rhoeo*, would not give triploid (trisomic) inheritance. The chromosome assortment would be irregular, and might approximate to random distribution of the extra chromosomes, as Van Overeem found in *Oenothera*. Nor could, as stated above, a 'gigas' form of *Oenothera* or *Rhoeo* be taken as a sample of true tetraploids.

"The following symbols may be suggested for these cases. For the ordinary forms with complete chains, $n+N$, instead of $2n$. Thus the 'semigigas' will be $n+2N$ or $2n+N$; and the 'gigas' will be $2n+2N$. *Oenothera lamarckiana* is (as Cleland demonstrated) a mixed form, namely, $(n-1)+(N-1)+2$."

Diploidy of the Cladocera Male

Cladocera males have long been supposed to be diploid in chromosome make-up and this result has been, during the past year, confirmed by Allen for *Moina*. Banta has secured genetical evidence on this point. Individual males of *Daphnia longispina* from three different lines which are known to be heterozygous for one or more mutant characters were mated with 6 to 18 sexual-egg-bearing females of a stock known not to carry these dominant mutant characters. Sexual eggs were produced, which hatched poorly, but from all of the crosses which have yielded more than a single individual, namely 4 in number, we have had offspring of two kinds, those with and those without the mutant character. In two of these crosses two mutant dominant characters were involved and segregation in the male occurred for both characters. Since it is obvious that segregation is not to be expected in a haploid male, the demonstration of segregation in these males constitutes genetic evidence that they are diploid.

DEVELOPMENT AND ITS GENETIC CONTROL

Growth in Mammals

One of the most remarkable and apparently simple processes of development is that of the growth, or the increase in size, of the developing organism. We have accordingly concentrated on this topic as a means of getting an insight into the way in which the chromosomes do their work of directing the course of development and we have made use of our long inbred lines of mice whose genetical possibilities are well known. In connection with the study that is being made on prenatal deaths in mammals, MacDowell has made a series of careful determinations of the weight of the embryonic mice at precisely determined ages. In cooperation with Dr. Ezra Allen 959 mouse embryos have been weighed, derived from 115 litters of ages ranging from 8

to 18 days after conception. Also 192 embryos were taken by Dr. Allen from 23 litters aged 5 to 7.5 days from the fertilization of the egg. Most of the latter group have been sectioned and studied for determining the period of the primitive streak in mouse embryos. The main difficulty in finding a true curve of prenatal growth is due to the fact that different embryos at different ages must be assumed to give the curve that would be given by the same embryo at different ages. We can approach the desideratum of a curve derived from the same embryo at different ages only if the diverse embryos studied are comparable with each other.

To make the embryos as comparable as possible each detail, starting with the birth of the mothers of the embryos, was carefully standardized. In order to secure the greatest vigor of growth with a minimum of segregation of differentiating characteristics the embryos were triple hybrids, resulting from the union of three highly inbred and unrelated strains. The time of copulation was known within an hour; 85 per cent of the vaginal plugs observed resulted in pregnancy. The technique of dissecting the embryos from the membranes and placentæ and weighing them was of as high a degree of accuracy as the observers could secure. All embryos were taken out under a binocular microscope. The smallest ones were dissected from their envelopes in Locke's solution under a magnification of 30 diameters. The weights of the older embryos, taken to 10 days of age, were recorded to four significant decimals of a gram on a Sartorius balance. Younger embryos were recorded to the fifth place of decimals with a working accuracy within 1/100 mg. This was made possible by a Troemner assay balance with which triple-checked precision button weights were used. Daily readings of the zero position and of glassware kept a constant check on atmospheric variables. All of the weighing was done by Charlotte G. MacDowell. The analysis of data secured from these weighings leads to the following conclusions.

INFLUENCE OF NUMBER OF EMBRYOS AND OF SEX ON WEIGHT

In consequence of the hybrid nature of the embryos weighed the litters were large (averaging close to nine embryos) and showed a small variability in numbers. Within the range of variability we find no correlation between litter size and weight, even in the last two days before birth. The average weight for males is slightly higher than for females on the last (18th) day of gestation, but at no earlier age is there any appreciable difference. These two results simplify the study of normal prenatal growth and justify the practise of averaging together both the sexes and litters of different sizes.

PRENATAL GROWTH A LOGARITHMIC FUNCTION OF EMBRYO AGE

The average weights for the different days, plotted on logarithmic paper, lie close to a straight line, when age or time of development is computed from a point 7.2 days after the moment of conception. This modification of the age was shown by graphic methods to give the closest fit to a straight line. The slope of the straight line was determined by the method of least squares. The line is expressed mathematically by the following equation, which gives the expected weight (W) of an embryo at any conception age (t) in days, reduced by 7.2 days in order to give embryo age in days. This product is multiplied

by ten to express the units in tenths of a day in order to avoid the use of minus logarithms.

$$\log W = 3.647 \log [10 (t-7.2)] + \bar{8}.6587$$

The use of 7.2 days from fertilization of the egg as a zero point of embryo age is justified by the embryological studies of Allen made on timed and sectioned embryos of our stock, as well as by the work of Sabotta and others. These show that about 7 days of embryonic life are, in the mouse, consumed in the work of implantation, including the development of the trophoblast and the primitive fetal membranes. It is not until 7 days have passed that the group of cells out of which the embryo proper is to develop begins to differentiate as indicated by the formation of the primitive streak. Since the embryo proper first begins to differentiate at the end of 7 days that period marks the probable zero point for its development. The fact that it is possible to estimate the time of the beginning of the embryo from the growth curve of the embryo indicates that before the embryo proper is started the growth of the blastula and of the egg cylinder follows an essentially different law from that shown by the embryo proper. By the time the egg cylinder is well implanted in the uterine tissues the maternal hemoglobin becomes available as embryotroph. With the food supply well established the organization of the embryo proper is begun and growth proceeds at a tremendous rate that, considering the weight of the embryo, is never again equaled. MacDowell has shown that this relation between the beginning of the embryo and a logarithmic straight line is not an accidental matter by comparing his data from the mice with the data of other investigators for the guinea-pig. The latter data also conform to a logarithmic straight line when embryo age is taken as 12 days less than conception age, according to the formula $\log W = 3.987 \log (t-12) + \bar{5}.1839$. In this case also the embryological studies that have been made agree with the graphic estimate made, indicating that the end of the twelfth day is the beginning of the embryo proper. MacDowell calls attention to the fact that, despite the long gestation of the guinea-pig (64 days), which covers the period of infancy—post partum in many mammals—a single formula applies from the beginning of the embryo proper to time of parturition. This has considerable importance in the analysis of the factors that shape growth curves. Given the uniform conditions of intrauterine life the increase in weight of the guinea-pig during its stage of infancy continues to show the same law as is shown by the earlier intrauterine stages—stages which alone are represented in the mouse.

MacDowell has extended this method of analyzing growth to the chick. The published data follow a straight line, when embryo age is taken as 12 hours less than the incubation age.

$$\log W = 3.436 \log [10 (t-0.5)] + \bar{7}.626.$$

This formula was determined graphically before it had been ascertained that Duval gives 12 hours as the time of formation of the primitive streak.

The prenatal growths of these three animals not only agree in indicating the time of the beginning of the embryo proper but they also show that these animals have similar growth velocity constants during embryonic life. The logarithmic straight lines, based on the respective embryo ages are not far from parallel, as shown in figure 1. The main differences in development depend

upon the amount of material involved in the first organization of the embryo proper and in the length of prenatal life. From these considerations MacDowell concludes that the growth of different animals may be compared more accurately if age is counted, not from conception, but from the beginning of the differentiation of the embryo proper. A detailed account of this work is given by MacDowell and Allen in a paper that is in press under the title of *Prenatal Growth of the Mouse.*

OCCURRENCE OF PRENATAL MORTALITY

Records have been kept by MacDowell and Allen on all degenerate embryos in timed litters. In most cases these consisted of a small placenta, about 3 mm. in diameter, not much degenerated, with an embryo and membranes represented by a dark, decomposed patch on top. Rarely, a slightly decomposed embryo, with complete membranes was found. If all such cases be added to the number of living embryos the total number of membranes found on successive ages from 8 to 18 days fluctuates about a horizontal line and shows no tendency to decline with increasing age. This shows that, even if death occur as early as the eighth day, some evidence of the embryo will be found at the eighteenth day and the number of degenerates found at any age will be the accumulated total. The curve of the percentage of all implants that are degenerate rises from 4 per cent on the eighth day to 11 per cent on the eleventh day. From this time on there is no further rise. Thus the majority of prenatal deaths occur early during the period of rapid organogeny.

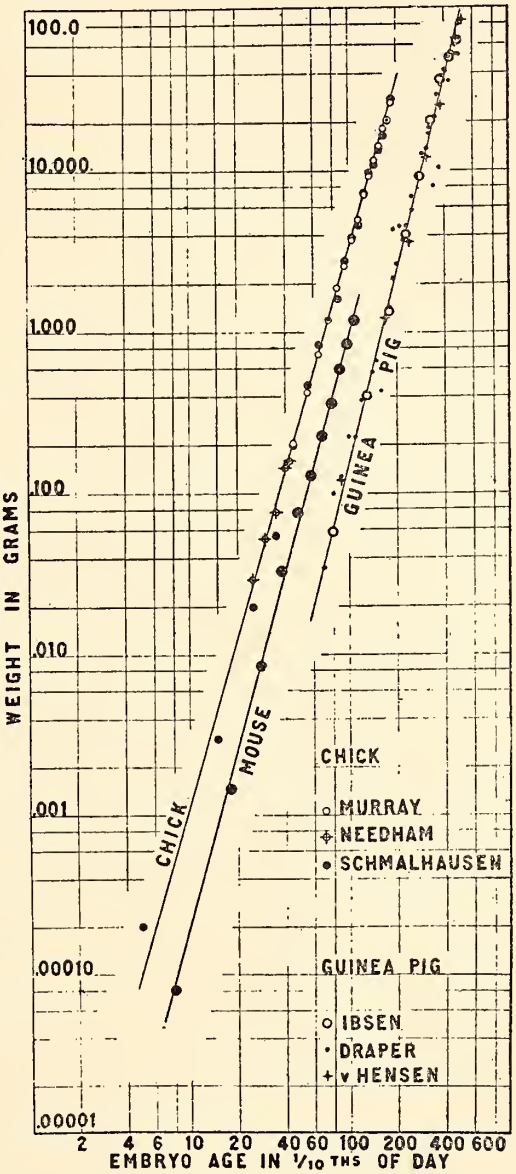

FIG. 1. Growth curve of mouse, guinea-pig and chick, when plotted on double logarithmic paper. Embryo age continuing from the time of formation of primitive streak.

EARLY POSTNATAL GROWTH OF THE MOUSE

MacDowell has continued the study of the growth and weight of the mouse for some days after birth, using the same experimentally controlled, genetical material as that employed for the study of intrauterine growth. The ages of

the mice were counted from as near as possible the hour of fertilization of the egg and they were weighed at that hour each day, without regard to the hour of birth, which usually occurred during the nineteenth day. All of the mice were nursed before the first weighing and litters were reduced at birth to two males and two females. This gives abnormally small ratios and provides an abnormally large amount of food to each individual. Male averages are higher than female averages from birth. The line of growth for the first seven days after birth has a slightly different slope from that of the prenatal averages. The curve of the daily average increments reaches, in this case, its highest point on the eighth day after birth, when the weight is 7.8 grams. This is over twice as much as the average highest prenatal increment. Beyond the eighth day the average increments decline.

MODIFICATION OF THE POSTNATAL GROWTH OF MICE FOLLOWING OPERATIONS ON THE MOTHER

A detailed study of postnatal growth in the mouse was carried out by Davenport with the assistance of Miss Newman in weighing the mice. Weighings were carried out from birth to over 100 days, both on control mice and on the offspring of mothers which had undergone certain operations on the thyroid gland. The purpose of this investigation was to determine the extent to which the course of growth could be changed by alterations of the thyroid gland before the period of gestation began. A total of about 1,000 mice was weighed, and of these 392 constituted a control. It appeared, at the outset, that the rate of growth of the young is very much greater in smaller litters and thus the study was made separately on litters of 7 to 5 mice and of those of 10 to 7. The curves of growth of the different sexes and of mice born in the different seasons of the year were found to be not entirely comparable. In this series the maximum of daily increments was found at about the sixth day. This was followed by a decline to the eighth day and then by an increase of absolute increments to the twenty-sixth day, after which the increments of growth declined again. The growth curve of the large litters, though growth is smaller, has the same total form. The reason for the relatively slow growth of the large litters is, doubtless, that each mouse receives less milk, but the effect of this diminished nutrition persists long after weaning—to 100 days of age or more. In fact, the limited milk supply obtained by the large litters seems to be a persistent handicap to the growth of these mice. An attempt was made to alter the growth curve by removing the thyroid gland from the mothers. The operation was performed by Dr. W. W. Swingle, then of Yale University. The mice born of such completely thyroidectomized mothers developed a little faster than the controls. At the end of 67 days they weighed on the average 325 mg. more than the controls.

The offspring of mothers in which the thyroid gland has been merely singed at a period before the onset of gestation grew less rapidly than the controls. Thus in litters of 7 to 5 mice the offspring of the treated mothers at 36 days weighed 2 grams less than the controls. It appears that the cauterization of the thyroid gland of the mother, which includes also partial destruction of the parathyroid gland, has its effect in two ways: first, by altering the chemical constitution of the milk, probably by reducing the calcium and, secondly, presumably by the production of some substance directly injurious to growth

so that the young of thyrocauterized mothers, though nursed by control mothers, do not grow as well as the young of such control mothers.

Attempts were also made by Davenport to modify the postnatal growth by removing the gonads from both male and female mice at approximately ten days of age. Despite the severity of the operation the growth was only slightly retarded. Although the analysis of the data is not yet complete it seems probable that the rate of growth of mice so operated on is not changed in any important respect. Especially the pre-adolescent spurt of growth which occurs at about 26 days, seems not to be modified in the gonadectomized animals, so that the retardation of growth which occurs nearly simultaneously with an increase in the size of the gonads is not to be ascribed to secretions derived from the gonads. One can only infer that the time relations between the enlargement of the gonads and the retardation in growth processes is not a causal one. There must be some other retarding factor which arises even in the absence of the gonads that is responsible for the slowing-up of growth after the twenty-sixth day. Since the slowing-up occurs to about the same degree in small litters and large litters it can not be due to a change in the milk supply, toward the end of the lactation period. The retardation of growth continues after weaning when the mice are furnished with all of the food that they can utilize. The factor responsible for the pre-adolescent retardation in growth remains to be discovered. It may be added that the experiment on effect of thyrocautery of the mother on the growth of the offspring was undertaken to throw some light on the production of human dwarfs, especially of Mongoloid dwarfs. In the case of such human dwarfs there is frequently a history of severe emotional or physical strain in the mother and the experiment cited suggests that the disturbance of the thyroid secretions due to such stress may be, at least partly, responsible for the production of Mongoloid dwarfs. At the same time it has to be admitted that, partly because of the difference in differential growth in mice and men, the alterations produced by the thyrocautery of the mother mice are not likely to be paralleled in the human Mongoloid dwarfs.

INFLUENCE OF PREGNANCY ON GROWTH OF MOTHER

MacDowell and Allen were able, by studying the weights of mothers at the time of conception and again after the removal of the embryos, membranes and placentæ, to secure a curve showing the change in mother's weight due to pregnancy. Practically all of the mothers had obtained mature weight before conception. The youngest ones (three months old) were growing at the rate of 0.075 gr. per day. The best smoothing of the averages showing the growth during pregnancy is a straight line giving a daily rate of 0.5 gr. If liberal allowance is made for possible growth independent of pregnancy, by supposing that all mothers were growing at the rate of the youngest ones, we reach the conservative conclusion that pregnancy increases this rate at least 5 times.

SEX STUDIES

It is a statistical fact that has long been known, that the proportion of the sexes in man and mammals deviates somewhat from the expected proportions of 50 to 50. The causes responsible for this deviation and the control of the proportions remain unknown. We have seen that in the fly *Sciara*, the

method has been worked out by which the sex ratio is under the control of the mother or, more specifically, of her eggs. It is believed that in birds and mammals by certain procedures the proportion of the sexes can be disturbed. Especially Riddle points out in pigeons over-work of the female in the egg-laying process results in an increase in the proportion of males.

Sex Ratio and Alcohol

Various attempts have been made to influence the sex ratio through the differential susceptibility of the two kinds of sperm to different treatments. Several papers by Bluhm and others profess to have secured results from the alcohol treatment of male mice. Since these results are open to the criticism of being based on too small numbers and being insufficiently controlled, MacDowell has undertaken the re-investigation of the subject. Male mice were subjected to the heaviest alcohol treatment that they could survive, five times a week by the inhalation method. These mice were mated with normal females whose successive litters were sired, alternately by a treated male and his untreated litter mate. The control of all possible influences besides the alcohol treatment was carried out in great detail. From treated fathers 2,153 offspring were sexed, giving a ratio of 49.55 per cent males; from control fathers 2,285 offspring, giving a ratio of 50.70 per cent males. The deviations of these ratios from 50 per cent are less than their probable errors. In order to meet the criticism that might be raised that failure to obtain an effect might be due to the method of administering the alcohol, since in MacDowell's experiments the alcohol was taken in through inhalation while in cases reporting positive results the alcohol was injected, a small experiment was carried out with exactly the same treatment as Bluhm, namely 0.2 c.c. of 20 per cent of alcohol injected subcutaneously on alternate days. The treated males in each experiment were brothers; the mothers were sisters. The mothers were 3 months old at the time of mating and only first litters were used. All question of loss at birth and later and any late prenatal mortality was removed by sexing the offspring at 14 days after conception. At this time the gonads are clearly differentiated by shape, size, position and pattern of vascularization. The difference in position of the gonads in the two sexes can easily be detected through the body-wall, but this method of determining sex was checked by the dissection of each embryo. MacDowell's results so far are based on more individuals than those of any previous worker obtaining a positive result. From treated fathers, 651 embryos were obtained, giving 48.1 per cent males; from control fathers 575 embryos give 52.3 per cent males. A further control is given by the ratios obtained from embryos of like ancestry observed at other ages; 842 embryos of which 54.0 per cent were males. This gives unquestionable support to the result obtained by the method of inhalation and eliminates the difference in method of treatment as a possible explanation of the conflicting results.

Sex in Relation to Prenatal Mortality

Parkes has shown that the sex ratio of mice at birth and the size of the litter are not correlated and, as stated in the last annual report, it has been found in this Department that the sex ratio at birth and the number of prenatal mortalities, based on the corpora lutea, are not correlated. MacDowell recently

investigated the sex ratios in correlation with the percentage of degenerates actually found. Since the number of degenerates at any age has been shown to be cumulative, age can be ignored. MacDowell's data for this study includes 168 sexed embryos aged 14 to 18 days. The average percentage of males in litters classified by the percentage of degenerates found, starting with 0 per cent degenerates and proceeding by classes of 5 per cent range up to 25 per cent, are as follows, the number of litters being given in parentheses: 49.1 (81); 52.8 (23); 55.9 (21); 56.7 (13); 48.0 (12); 52.2 (12). Since the sex ratios show no tendency to change in accordance with the increase of the degenerates there is no evidence that degeneration has affected one sex more than the other.

When the sex ratios are calculated according to the age of the embryos the following percentages of males are found, the number of embryos being placed in parentheses : 13–14 days, 53.4 (406); 15–17 days, 55.8 (337); 18 days, 51.6 (248); 19 days, for the most part born, 54.1 (257). These two methods of classifying the prenatal sex ratios confirm the conclusion previously reached by MacDowell that in the mouse sex is not a factor in prenatal mortality.

Chemical Differences of the Sexes

Further studies of the biochemical differences in plants has been carried along two main lines during the last year: (1) The problem of the reducing capacity of the plant extract; (2) quantitative determinations of soluble sugars (A) and of fat (B). Miss S. Satina and Dr. A. F. Blakeslee report on the results, as follows:

"Tests with some new races confirmed the results previously obtained—viz, that the extracts of ♀ plants and plus races have, on the average, a stronger reducing capacity than the ♂ plants and minus races. More detailed investigations with green plants have shown the influence of the different stages of development on this reaction. A preliminary analysis of the extract of Mucors shows that the substances which are chiefly responsible for the reduction reaction belong, apparently, to the group of aromatic compounds (tannins, etc.). The reducing sugars are of secondary importance.

"The quantitative volumetric analysis of total, reducing and inverted sugars in Mucors (66 races) has shown that the amount of sugars is not high in comparison with other substances. The results obtained correspond with the figures given by other authors for higher fungi. The (+) races contain, on the average, more total and reducing sugars than the (−) races. In about 72 per cent of the pairs tested the plus race showed the higher amount of sugar. The differences in the amounts, however, are not high (mostly less than 1 per cent) and it seems unwise, at present, to stress unduly the apparent connection with sexual differences.

"Quantitative, gravimetric analysis of fat in 66 races of Mucors did not show any constant differences between the sexes. The content of fat obviously was in excess in the minus races of some species but showed the reverse in the races of other species. Control tests also showed how easily the amount of fat can be changed in the cultures of the same race by changes in various external conditions. Some species, and even genera, seem to be particularly sensitive to this factor (*Absidia* species) and the relative development of the aerial and substratum growth determines the amount of fat; i. e., cultures with aerial hyphæ have given 18 per cent of fat, while cultures from the same

race but showing only a thick substratum-skin have given over 40 per cent of fat."

A further study of the chemical and metabolic distinction of sex in pigeons has been completed by Riddle and Miss Burns. They find that there is less fat in the blood of the male than of the female pigeon. Riddle calls attention to the fact that this result coincides with work earlier reported on fowl's blood, and probably with all of the few adequate determinations thus far made in either higher or lower animals. It thus assists in demonstrating that fat metabolism is quantitatively different in males and females. Riddle also maintains that we now find this sex difference so widespread, and probably so constant when groups of individuals within the species are measured, that it is not to be regarded as a "secondary" sex character, but as a direct expression of the metabolic difference which he identifies with primary sex difference.

Manoilov Reaction in Relation to Sex

Miss Satina has continued, under Dr. Blakeslee's general direction, her studies into the significance of the Manoilov reaction as an indicator of sex.

Important light was thrown upon the significance of the Manoilov reaction in studies made by Riddle and Rinehart on the blood and tissues of pigeons. The results indicate that the Manoilov sex test is applicable to the determination of metabolic level, in general, and of sex only as a special case of this difference in metabolic level. From individual pairs of pigeons in which repeated tests were made the sex was usually correctly indicated by the test in the ordinary life stages, but much more often incorrectly indicated at the particular reproductive stages in which metabolic change is known or probable. The test rests purely upon a quantitative, not a sex specific qualitative, process, thus confirming results obtained by Alsterberg and Häkannson. This fact, however, is necessary to and is in conformity with Riddle's association of the test with metabolic state or level. The few, or numerous, failures of the test as a sex test are explicable under the view here developed. Riddle reports further:

"The blood of both male and female pigeons gives a lighter color (male reaction) in active than in inactive stages of the reproductive cycle. Blood from birds made to fly 10 minutes usually gives a lighter color than samples taken immediately before this period of exercise, but this result is probably influenced by blood lost for the first sample. Blood from younger birds gives a lighter color than is obtained from older ones. Aqueous extracts of active tissues (muscle, ovary, heart, gizzard) usually yield a lighter color than tissues presumably less active (liver, egg-yolk). The three glands of the oviduct each give lightest color when actively secreting, and progressively more color at stages more removed from active functioning. Extracts of whole embryos give lightest color when prepared from freshly killed embryos; decidedly darker color when obtained from embryos dead 1 to 3 days. These results reveal new precautions necessary for comparisons made with this test, and provide further evidence that the reaction is primarily a better indicator of metabolic rate than of sex."

Sexual Differences in Prenatal Growth and Death

Riddle has been led to some general conclusions concerning intrauterine fetal life and death in relation to sex of the embryo. The result of this exami-

nation is applied to the current conclusion that the mammalian and human male is "inherently weaker than the female."

"Male and female fetuses are alike forced to undergo their development in a *female* environment provided by the mother. This condition, combined with the further probable fact that maleness (from the Y-sperm stage to adult life) has tendencies, demands and requirements other and greater than those of femaleness, provides unequal chances to male and female for unrestricted growth and health.

"An apparently sex-specific hormone (alcohol-soluble; from ovary, placenta, etc.) enters the fetal circulation and is responsible for a special phase of prenatal growth in the uterus of the female; in the mammæ and suprarenals (and thyroid?) of both males and females; in the prostate and Müllerian duct system of males. Adverse or antagonistic effects—edema and degeneration in some cases—have been described in the testes, prostate, penis and epididymis of males.

"The serological studies in progress at the Frauenklinik at Halle indicate that the mother's blood reacts to the fetus as to a foreign body. This 'antitestis' body probably enters the fetal blood and apparently induces a reaction in the male fetus. The mother's blood does not appear to react similarly against a female fetus.

"The vitamine B, protein and metabolic requirements in postnatal stages are probably unequal in males and females, and this difference is probably present during fetal life. Since these requirements are apparently greater in the male this should result in a higher male death-rate in that fraction of mothers whose nutritional status is near the border line.

"From the fact that an abnormally high proportion of males is found among the prenatal dead the conclusion is currently drawn by physicians, geneticists and others, that the male is inherently and genetically the weaker sex. This conclusion can be drawn only on the assumption that intrauterine environment is essentially equivalent for male and female. The facts discussed here show that such equivalence does not exist."

Experiments in Sex Control on Moina

The studies on control of sex ratio or, more strictly, the production of males, in *Moina macrocopa* which has been so successfully developed by Banta in collaboration with L. A. Brown have been continued during the year. The general principle seems established that female production is associated with the normal rapid rate of development of the mother and of the ovarian eggs; while male production is associated with a delayed rate of development of the mother and of her ovarian eggs at the critical period of sex determination, namely about four hours before the eggs are laid. This principle applies to all experimental results with whatever method of treatment. Crowding the mothers, low temperature, chloretone, etc., are all associated with a retardation of development and with male production. With a given method of treatment the amount of retardation and the percentage of males resulting are fairly closely correlated. Conversely, the means taken to overcome the retarding effect of crowding and thus the reduction, or elimination, of male production in bottles in which it would, otherwise, occur is effective roughly to the extent to which the stimulant accelerates the development of the mothers and of their eggs during the late ovarian stage.

Two additional substances have been found which, when judiciously applied, cause increased male production in semi-crowded bottles of *Moina macrocopa*.

PHENYL URETHANE TREATMENT

Seven series of experiments were carried on with phenyl urethane. These involved 1,450 mothers and more than 13,200 young. In three of these series there was no effect on male production (and no retardation), but in the other four series the treated mothers produced an appreciably higher precentage of males than the untreated mothers. The total for all seven experiments gave 39.2 per cent males in the bottles treated with phenyl urethane and 22.3 per cent males in the untreated controls.

KCN TREATMENT

The cyanide treatments caused reduction in the rate of development and were associated with increased male production in crowded bottles. Four earlier series treated with cyanide failed to show increased male production; but 14 of the later 16 series so treated showed increased male production in the treated bottles. Some of the treated mothers gave only a slightly increased male production but many of them gave materially increased male production, ranging from 40 per cent to several hundred per cent more than the untreated mothers.

GLAND SUBSTANCES NOT SPECIFIC FOR MALE PRODUCTION

Having reconfirmed the fact that treatments with extracts of adrenal cortex and thyroid of the ox accelerated the rate of development and lowered, or eliminated, male production in crowded bottles, Banta and Brown next added thymus extract to the water and found that its effect was the same as that of the adrenal cortex and thyroid. They then tried extract of desiccated muscle of the ox (kindly prepared gratis especially for us by Carrick and Co., New York) and found that it was fully as effective and as effective in the same sense as the gland substances used; i. e. the rate of production was accelerated and the rate of male production decreased. From this it is concluded that the adrenal cortex and thyroid gland extracts are not specific in their action and that proteins or other organic substances found in ox tissue are the effective agencies involved. Possibly it is merely the food of *Cladocera* (certainly, in most of our cultures, largely bacteria) which is affected. In any case the muscle tissue extract is, like the gland extracts, an effective agent in modifying rate of development and male production, the matters of concern in the present experiments.

Cytological Studies on Sex-cells of Moina

In the last few years Banta has worked out a method of inducing the production of males in parthenogenetic strains of daphnids. It is known that by the application of certain agents that retard the rate of development at a definite time before the eggs pass from the ovary to the brood chamber a large proportion of males is produced. As this period is near that of the probable maturation of the egg, it seemed desirable to ascertain what cytological changes are occurring at this time and what cytological differences there may be between the eggs that are to produce females and those that are to produce males. Allen has devoted some months to a cytological study of Banta's material and has obtained the following results. First, the large mass of nucleolar material in the eggs of *Moina macrocopa*, which stains like chro-

matin, is not chromatin but is probably used as food. Second, the number of chromosomes in *M. macrocopa* is probably 22. Considerable evidence is at hand that, as predicted, the male somatic number is not haploid. The number is the same in both parthenogenetic and sexual eggs. Third, the peculiar grouping of the chromosomes during maturation makes it very difficult if not impossible to tell positively whether sex determination depends upon chromosomal dimorphism. Sex seems to be determined in parthenogenetic individuals during the latter part of the growth period of the egg rather than at the time of maturation. Fourth, there is no difference between the parthenogenetic and the sexual eggs at their early stages of growth. In the sexual egg the peculiar yolk is differentiated at about the time that the process of degeneration sets in with the nurse cells. The differentiation of the sexual egg and the degeneration of the nurse cells are controlled by external conditions.

GENETICS OF SPECIAL TRAITS

Cladocera

The observations of mutations occurring in parthenogenetic reproduction, referred to in earlier reports, have been continued. The excavated head mutation is being carried on with selection. The short beak mutation is an excellent character in that it is expressed in every phænotype and thus its genotypical presence is recognized.

INHERITANCE IN SEXUAL REPRODUCTION

Crosses between mutant and wild-type stocks of *Daphnia longispina* have been continued by Banta and his associates. The mutations continue to behave as Mendelian dominants, heterozygous always in the parent stock. The new developments show many sterile, nearly sterile, and fertile but physiologically weak individuals which occur along with normally vigorous, sexual offspring. Such sterility (complete or partial) is found especially among young from inbred lines which previously had had a long parthenogenetic laboratory history. The best hypothesis seems to be that in the long parthenogenetic line lethal or sublethal mutations had occurred. With segregation and recombination in sexual reproduction these harmful mutations become effective, resulting in smaller hatches and many inferior offspring in the sexual young from individuals derived from the old parthenogenetic stock. This hypothesis finds support in the fact that the stock of the longest parthenogenetic history, when inbred, has given the poorest hatches, lowest viability and greatest sterility among its sexual offspring. These defects in viability and fecundity have become most obvious in the later generations derived by sexual reproduction. Table 1 gives some of the recent data, tabulated according to the number of grandparents derived from the strain XI that were in the ancestry of the F_2 generation recently derived by sexual reproduction. This tabulation may, at the same time, be presumed to indicate the number of chromosomes derived from the zygotes from the strain XI stock. The table clearly suggests that there is a distinct relation between the number of grandparents of the long parthenogenetic strain XI (involving over 360 parthenogenetic laboratory generations) from which these animals have been derived and the hatchability of the eggs, the viability of the hatched young and their fertility. When only 1 grandparent of strain XI is involved about 6 per

cent of the hatched young were sterile, including those that died early; when 2 grandparents of this strain were involved the percentage of sterile hatched young was approximately 47. When 3 grandparents were involved the percentage rose to about 71 and when all 4 grandparents the hatchability was almost nil, only one young—and a sterile one—having been hatched. These results support the hypothesis of lethal and sublethal mutations.

Certain occasionally great but often slight physiological differences are noted among the hatched sexually reproduced young and individual clones derived from them, such as variations in rate of development, in frequency of

TABLE 1—*Relation between number of strain XI grandparents and hatchability of sexual eggs and percentage of sterility in granddaughters*

One XI G-parent			Two XI G-parents			Three XI G-parents			Four XI G-parents		
No. Eggs	No. Hatched	No. Sterile	No Eggs	No. Hatched	No. Sterile	No. Eggs	No. Hatched	No. Sterile	No. Eggs	No. Hatched	No. Sterile
G 86	28	1	E 255	21	11	HR 235	18	14	FQ 68	1	1
K 98	20	2	FM 86	1	1	EO 34	3	1			
			GL, GN, GR 333	22	9						
			HN 85	5	1						
			I 117	9	5						
			J 516	14	10						
			L 77	7	0						
			M 76	7	3						
Totals											
184	48	3	1,545	86	40	269	21	15	68	1	1
Per cent hatched...26.09				5.57			7.81			1.47	
Per cent sterile.... 6.25					46.51			71.43			100

broods, viability and occurrence of sterility among the parthenogenetic young. No such range of physiological variation is found in the parthenogenetic line. The study of the physiological differences between clones derived by sexual reproduction is being continued by two graduate students from the University of Minnesota, who, during this summer, are temporarily at Cold Spring Harbor.

THERMAL CLONE

A year ago, during a period of hot weather, there was hatched from inbred, old parthenogenetic stock a female who produced several broods of parthenogenetic young. Those that hatched during a low temperature died; those which hatched during the hot weather survived. This led to the hypothesis that the clone was adjusted to abnormally high temperature. The hypothesis was tested by keeping the mother and daughters at about 27° C. They thrived there. Further experiments show that this clone is vigorous so long as maintained at a temperature between 25° and 30° C., but will not survive at the optimum temperature for the other stocks, about 20° C. Ordinarily

27° C. is soon fatal to our Daphnids. The new clone which is adjusted to a high temperature is much more quickly immobilized at a low temperature, 1° C., than the parent clone. The thermal clone is killed by 43° C., while the parent stock succumbs at 38°. This experiment throws light on the possible origin of thermal races in nature. Instead of being the product of long acclimatization they may be the result of mutations and genetic recombinations that arise quite suddenly. Survival at the high temperature might be followed by still further mutations, enabling the descendants to live at still higher temperatures and thus an adaptation to very high temperatures would finally be obtained. Banta's studies in selection in parthenogenetic reproduction, of reactiveness to light, of sex intergradedness and of excavated head show that a mutation in a given direction may be followed by further mutations in the same direction and thus the effects may be cumulative.

INHERITANCE OF SHORT BEAK

This character has been involved in a few of Banta's crosses. In two matings between short-beak and wild-type stock, 3 out of 7 individuals have short beak. From these and other data, involving small pedigrees, it appears to be another Mendelian dominant, heterozygous in the parent stock, so that the three mutant characters thus far studied are all dominants, heterozygous in the stocks in which they first appeared.

EXCAVATED HEAD

In crosses involving parents heterozygous for excavated head by wild type, 32 offspring bear the excavated head character and 35 are wild-type, approximating the calculated 1 : 1 ratio. When both parents are heterozygous for excavated head, then out of 30 offspring 19 show the excavated head character and 11 are of wild-type. The numbers are small, which probably accounts for the failure to closely approach the expected 3 : 1 ratio.

Race Differences in Metabolic Activity in Pigeons

The attempt made by Riddle, during the past six years, to establish various races characterized by large or small endocrine size is being actively continued. The result of the work of the present year strongly supports the view that, in addition to large and small "thyroid races" already reported, we now probably have some races characterized by short and long intestines. The short intestines are probably correlated with small pituitaries and the long intestines with large pituitary glands. It appears also that the intestine length is shorter (−5 per cent) in males than in females. In connection with the work of establishing races characterized by the above-named differences data are being accumulated on the hereditary behavior in crosses of these various endocrine races. The principal crosses for the races of ring doves characterized by extremes of thyroid size or intestine length have now been made; additional numbers in later generations should, however, be accumulated before conclusions are drawn.

The study of the basal metabolism of pigeons that is being conducted in collaboration with Dr. F. G. Benedict and the technical assistance of Miss Edith Banta is proceeding favorably. At the outset it was expected that three years would be necessary to settle the main questions involved, together with the answer to the problems that would require solution in work on this untried animal. At the present time the technique of measurements has reached a

high stage of development. Many usable data are already at hand. It now seems probable that by the end of the proposed three-year period adequate and reliable data will have been obtained for a demonstration of the metabolic status of the two sexes in adult doves and pigeons. By that time there will have been determined, also, the relative metabolic status of various races of doves and pigeons characterized by high and by low thyroid size. It is believed that the same will have probably been accomplished for races of large and small pituitary size; and still other results bearing on race, season, the reproductive cycle and other points are confidently expected. From these studies it has already been definitely proved that in our strain of "scragglies," the individuals of which have an imperfect feathering, the basal metabolism is extraordinarily high. The very desirable answer to the question of possible changes in basal metabolism of the female at ovulation will soon be available.

Riddle, with the assistance of Miss Flemion, has undertaken an extensive investigation of the effect of transplanting the anterior lobe of the pituitary body of the adult into immature pigeons of 3 weeks to 3½ months. More than 400 anterior lobes have thus been utilized. 10 to 20 transplants are made into each immature bird. There is little evidence of survival of the transplants, though the histological study of such as have been recovered has not yet been made. It is clear that favorable effects on growth of the body have not been produced, and some evidence of unusual intestinal stasis has been found in the treated birds. The effects of the transplantations on the time of sexual maturity can only be known after the birds have developed further.

Ring Doves

A new mutation has appeared in the ring dove that Dr. Riddle is breeding. This somewhat resembles the ataxia earlier reported in our common pigeons but shows certain differences and is provisionally called "cephalic tremor." The condition is a Mendelian recessive. It manifests any degree of development and, except in extreme degrees, does not seriously interfere with the breeding of these individuals. This mutation has appeared in both of our "cross bill" races.

The Thoroughbred Horse

The investigations into the inheritance of traits of the thoroughbred horse are being continued by Laughlin. Mr. Walter J. Salmon continues his generous support of this research. The investigation has demanded the working out of quantitative expressions for the traits and performance of horses.

QUALITY OF PERFORMANCE

The principal advance of the year has been made in the development of standardized measures for qualities which heretofore have had to be considered descriptively, or at best comparatively, between individual horses. The general racing ability of a horse is called its Biological Handicap. Before the present investigation was begun, the gage of this quality depended upon the general judgment of skilled persons. Early in this investigation a reference system was used which rates a horse by comparing his performance in each of the best 25 per cent of his races with the performances of horses that have been most carefully standardized by the method of general judgment. The third method, developed during the year, is based upon the mathematical inter-compensations of distance, weight, age and sex in relation to speed and,

consequently, to racing ability. This provides a Biological Handicap system which is based upon absolute rather than relative performance. As a result of analyzing all American speed records since 1906, standards of performance classified by distance, age, weight and sex have been worked out. In any given race the Quality of Performance is the standard absolute seconds per furlong for the particular age, sex, weight and distance divided by the actual absolute seconds per furlong made in the particular race. By calculating their respective Q. P.'s, it is thus possible to give comparative quantitative ratings to two horses of different sex and age, which carried different weights and which ran different distances. The practical tables for using this system have been developed for colts, and similar tables are now in process of computation for geldings and fillies.

SPECIAL ABILITIES

The development of a method for the computation of Quality of Performance, for any complex of distance, weight, age and sex, has made possible, in turn, the development of quantitative measures of special abilities which, taken together, constitute racing ability in general. The most important of these special abilities which Laughlin has thus far considered are named and measured as follows:

Distance-going ability—This is equal to the mean of the products of the *Quality of Performance* by the *Furlongs Run*, in that 25 per cent of all races run by the particular horse which give the highest values for these products.

Weight-carrying ability—This is measured by the mean of the products of *Quality of Performance* by *Pounds Carried* in that 25 per cent of all races run by the particular horse which give the highest values for these products.

Age-ability, or ability in relation to age—This considers both earliness of development and duration of years during which the individual horse continues to race successfully. In general, it is found that the best racing ability (i. e., the age of maximum ability) occurs in fillies at 2.5 years of age, in colts at 3.5 years and in geldings at 5.5 years. For earliness in coming to hand, "juvenile age-ability" is equal to the mean of the products of *Quality of Performance* by *Maximum Age-Ability minus Actual Age*, in the best 25 per cent of all races run before the age of maximum ability. Similarly, after the age of maximum ability, for the particular sex, "mature age-ability" is equal to the mean of the products of the *Quality of Performance* by *Actual Age minus Age of Maximum Ability*, in the best 25 per cent of all races run after the age of maximum ability. "Best" means the highest values for these products.

Mud-running ability—Because of the absence of quantitative evaluation of track condition, the measurement of this ability proceeds slowly. With these limitations Laughlin used as a measure the mean of that 25 per cent of the highest values for the following quotients made on heavy, muddy and sloppy tracks:

$$\text{M. R. A.} = \left(\frac{\text{Actual Q. P.}}{\text{Mean Q. P. for B. H.}}\right) \div \left(\frac{\text{Mean Q.P. for American tracks for the particular condition.}}{\text{Mean Q.P. for American fast tracks.}}\right)$$

Energy consumed in relation to speed—During the year work has been continued by Laughlin on an apparatus for measuring oxygen consumption and CO_2 production in the horse. Four different masks were built and each in

turn discarded for improvements in the qualities needed. A fairly satisfactory mask has been produced. Work is in progress on an air meter and air-sampling device usable on a horse either at rest or running. Acknowledgment is made of assistance from Dr. F. G. Benedict, who has given advice in this matter.

Human Genetics

NEGROES, WHITES AND RACE MIXTURES IN JAMAICA

Under a special fund given by Colonel W. P. Draper, a comparative research is being made into the physical and mental traits of full-blooded negroes, whites and mulattoes in the tropics. The work under the fund was organized by a committee consisting of W. V. Bingham, E. L. Thorndike, Clark Wissler and C. B. Davenport. Morris Steggerda, a graduate student of the University of Illinois, was secured to gather the data. After a period of training he, accompanied by Dr. Davenport, went to the island of Jamaica in September 1926. With the aid of the American consul, Mr. Joséde Olivarez, they were introduced to various officials of the Government by whom they were hospitably received. Mr. Steggerda returned to the United States in the middle of December and had further consultations with the committee. He returned to Jamaica in January and has worked there continuously until the time of this report. It is expected that he will return to the United States in October and superintend the tabulation of the results, which has already been begun.

The work consists of two main parts—the comparative physical and mental measurements of 150 persons of each sex, who are as nearly as possible living under the same conditions, of about the same social stratum and representing the white race, full-blooded negroes and hybrids between them. Besides the mental and physical measurements, several investigations into physiology are being made, such as oxidation of the blood, and blood grouping and, with the assistance of Dr. F. G. Benedict of the Nutrition Laboratory, a study of basal metabolism. Acknowledgment will be made in due time of the great services afforded by numerous residents of the island. We are especially fortunate in having the collaboration of Dr. B. E. Washburn of the Rockefeller Foundation, who is carrying on hook-worm investigations in the island. During the month of June, Mr. Steggerda visited the Island of Grand Cayman in order to add to the number of whites. He was also able to secure data on a number of white families which have lived for some generations at Seafordtown, Jamaica. Over 4,700 sheets of reports are on file. Codes have been drawn up and punch cards printed for the sorting and tabulation of the data obtained.

A second series of observations being made by Mr. Steggerda and which is included in the sheets enumerated above has to do with the ontogeny of the representatives of the negro-white races and the mulattoes in the island of Jamaica. Several hundred cases at the Lying-in Hospital and children at the Crêche and at the Mico Training School have been studied. The result will give us a good picture of the development of the negro from birth to maturity.

In preparation for the work of Mr. Steggerda a set of drawings was prepared during last summer by Richard H. Post, to be used as a test of capacity for form discrimination. This work was done under a grant made by the

Eugenics Research Association. The test consists of about 48 pages each of paired circles and near circles, isosceles triangles and near isosceles triangles, regular hexagons and near regulars. In taking the test the subject has to decide whether the right-hand figure in each pair is the regular or irregular one.

The form-discrimination test has been applied by Miss Anna E. Lawson, Principal of Public School No. 119, Borough of Manhattan, New York City, to a number of colored children of the sixth grade and also, through Miss Lawson's interest, by Principal Nathan Peyser of Public School No. 181, Borough of Brooklyn, to an equal number of white children of the same grade. It appears that the colored children of the sixth grade are about one year older than the white children of the same grade. Without making any allowance for difference in age, and using only an unweighted test, it appears that the colored children have possibly done slightly better in discrimination in form than the white children. A more detailed analysis of these results will be shortly published.

HEREDITY IN ARISTOGENIC FAMILIES

Dr. Banker has completed the preliminary work essential to an interpretation of school records for a study of heredity. He has demonstrated that the commonly accepted notion that teachers' marks should be distributed in conformity with the normal probability curve is incorrect. In theory, as in practise, their distribution is normally that of a curve skewed more or less to the high end of the scale; that is, with the mode above the mean. This is a conclusion reached in a paper published in the Journal of the American Statistical Association.

Out of the work has developed the more important result for the studies in heredity, that of finding a formula for an index of ability which may be computed from the conventional school records of student achievements. The formula, which has been derived as a result of laborious work over voluminous data, is written as follows:

$$\text{SAI} = \frac{\text{Mk}}{\text{CA}} \times \frac{\text{MGA}}{\text{GMk}}$$

In this formula SAI indicates any student's ability index; Mk is average mark; CA is chronological age; MGA the mental grade-age, i. e., the average mental age of the grade in which his work is done; GMk, average grade-mark. Under given conditions the second term may be tabulated as a constant. It appears that the index obtained, as above, compares favorably with intelligence quotients derived from standard group tests, which are accepted by educators as having a high degree of working efficiency. It has not been found practicable to compare the SAI with IQ's derived from Binet-Simon tests. It is hoped that this deficiency will be made good.

INFLUENCE OF HEREDITARY QUALITIES IN THE POPULATION OF THE HEAD-WATERS OF THE KENTUCKY RIVER

The researches of Dr. Estabrook in the Southern Appalachians are approaching an end. He finds that the expected stability of the population since the settlement of the valley, over one-hundred years ago, has actually not been realized. The environment has changed and migrations have taken place under the pressure of biological laws and under the lure of economic conditions.

One hundred and fifty years ago the Southern Appalachian area was heavily wooded, mostly with hard wood, and was populated only with roving Indians. About the year 1750 and for the succeeding years there was a movement of population westward into this wilderness. The fact of their migration indicates unusual energy and sturdiness in the migrants. The population was predominantly English, Scotch, Irish with many Germans and some French Huguenots. With the opening up, in the early part of the last century, of new and more easily traveled roads to the West, the immigration into this country largely ceased, until the very recent development of coal mining and timbering which have accompanied the building of railroads into the mountains. The isolation of the region for four to six generations has resulted in much inbreeding.

"The study of this problem has shown that there is great variation in the topographic features of this area: that certain topographic factors, some natural and others caused by man's activities, have controlled the economic conditions in the different regions of the area and that both topographic and resulting economic conditions have determined the type of people living in the various smaller sections by a definite process of selection in which the less energetic and intelligent individuals are forced into the regions with the poorer economic development, and those with more intelligence and activity gradually are moved into the situations and areas with better economic advantages or out of the mountain section into other parts of the country. The environment, then, has its main effect in the selection of the different types fitted for that particular environment, and the individuals react to these factors of the environment according to their hereditary characteristics and capacities for response to the particular situations that are presented by these various environments."

With the opening up of economically better opportunities in the West, a movement of population began again which took people from the Southern Appalachian area to the westward, especially to the Ozark Mountains, and later some to Oregon. At the time of the Civil War many families, particularly advocates of slavery, left the mountains and went to Texas. In 1900 there were 208 children in attendance at a rural county school of eastern Kentucky. At the present time 85 of these are in the rural local area where they were born; 12 are in other rural mountain areas near by; 21 are working in coal mines near the railroad in nearby counties; 14 are living in urban industrial areas and adjacent counties and 7 are in urban, non-industrial areas in the mountains; 23 have left the mountains and some of these are in other states; 4 died soon after leaving school and 42 can not be accounted for but are not living today in the region. In the last 10 years hundreds of families have left the whole mountain area to enter industry, either into automobile factories or cotton mills.

Family histories have been made in a number of different sections in the Southern Appalachians and extensive mental tests have been made in the schools. The mental tests show that—

"the lower the economic level of an area the lower are the scores in the mental tests given in the schools and the lower the general intellectual level of the families within that area. The studies also indicate that families with better intelligence are found in the areas with the better economic advantages. The

data also indicate that, in general, it has been the more energetic and intelligent men and women who have left the southern mountains for other regions."

In the earlier days, one family, as a rule, settled along one creek. The progeny remained near by. If the area was isolated the people seldom went far from home and propinquity was the deciding factor in matings which were then, necessarily, consanguineous. A higher rate of cousin matings is found in more isolated regions than in those where more exchange of population has taken place. A number of first cousin matings are found in the more favored sections where the general intelligence is higher.

While there is much crime, particularly man-killing, in the mountains, no particularly criminal families have been found.

HEREDITY OF GOITER

In collaboration with the Playground Athletic League and with the assistance of Mrs. Grist, a study has been made by Davenport of the conditions under which goiter has arisen in 104 families of Maryland. A special study is being made of the genetical factor involved. As is well known, goiter affects particularly the female. When both father and mother are goiterous all of the daughters (5) who have reached the age of 14 years are goiterous. In another case where the father is alone goiterous, though the mother has goiterous relatives, the daughters (2) are both goiterous. Where the father alone is goiterous, and there is no goiter on the mother's side, the daughters (3) are all goiterous. When the mother alone is goiterous, but the father has goiterous relatives, then about 90 per cent of the grown daughters are goiterous (40 cases). Even when the mother is affected and there is no evidence of goiter on the father's side the proportion of grown daughters who are goiterous is about 80 per cent. On the other hand, where neither father nor mother is goiterous the proportion of affected grown daughters is reduced to 60 per cent or less, even in these families which were selected because of a goiterous propositus.

HEREDITY IN ATHLETES

At the suggestion of the Carnegie Foundation for the Advancement of Teaching, especially its committee on athletics, directed by Dr. Howard J. Savage, and with the aid of an appropriation from it, we have undertaken a study of the hereditary factors involved in success in athletics. Richard H. Post undertook the task of collecting the requisite data and has begun an analysis of them. Correspondence was had with several hundred athletes and more or less satisfactory data obtained on about 40. Much time has been required for an analysis of methods of grading success in athletic performance.

Genetic Constitution of the American Population

The study on "Economic-Population Conditions" by Laughlin, mentioned in last year's report, has been completed. The survey which he began of deportable aliens in custodial institutions has also been finished during the year. A third research on "Inventiveness in Relation to Racial Descent" has been started. This study has for its purpose the determination of the Old World racial descent of the persons who were granted the 10,440 patents issued by the United States for the three months ending March 31, 1927. This is a

work in which the Eugenics Record Office, the Committee on Immigration and Naturalization of the House of Representatives and the Patent Office are collaborating. As earlier studies sought to measure racial quotas for various socially undesirable traits, the study of those who were granted patents seeks a comparative measure, by racial origins, of the socially desirable trait of inventiveness.

ADMINISTRATIVE RECORD

The combined libraries of the two sections of this Department comprise 12,050 bound books and numerous catalogued pamphlets. On June 30, 1927, the books in the archives of the Eugenics Record Office amounted to 1,838; field reports to about 68,000 sheets, special trait files, A & S, 29,710; Records of Family Traits, 10,580. We have also received over 2,000 sheets of various special schedules and 1,317 pages from the "Fitter Families" studies. The index cards now amount to 1,267,000. Some 37 schools and colleges, organizations and individuals collaborated by sending in Family Records and other data.