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DEPARTMENT OF GENETICS[1]

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GENERAL STATEMENT

This Department has always pursued genetics as a pure science. No considerations other than those of the working out of natural law, through the solution of fundamental problems, may properly play a part in our researches. Due to the fact that any organism is extremely complex, it was early seen that progress would best be made by each investigator working through the years with a particular organism, so that he might become thoroughly familiar with its genetical qualities. An advantage was anticipated in having a number of investigators, or groups of investigators, each working on a different organism, plant or animal. Thus would it be possible to separate the general and fundamental organic phenomena from the specific and trivial. Thus, of late years, our studies have been made of Datura; variegated plants, especially Delphinium; among insects, Drosophila and Sciara; several species of Daphnidæ; among birds, the Columbidæ; among the lower mammals, mice. About 23 years ago the human species was included in our program.

Now, Homo is not a good animal for genetical work. The time between generations is much too long; litters are too small, with usually only one at a birth, and the total progeny of a pair absurdly small; matings are uncontrolled and, under the mores, uncontrollable. The long time between generations would not be so bad if adequate records were kept of morphological and physiological characteristics, including performance. But such records are sparse indeed; and there are obstacles to obtaining the records.

However, despite all these difficulties, man offers certain advantages. In no other species has the technique for individual analysis been so fully worked out, thanks to the anatomist, physiologist, pædologist, psychologist, psychiatrist, endocrinologist, roentgenologist, and investigators in all the different medical and surgical specialties. Certainly in the field of inheritance of mental traits the human material is unsurpassed.

Moreover, even if Homo is poorly adapted to the discovery of new genetical principles, the testing out of such principles as have been worked out in other organisms is conceived to be of great importance. Too long have the problems of human well-being and progress been almost exclusively in the hands of philosophers and environmentalists, including sociologists and medical men. These have, at times, resented the entrance of the geneticist into the territory on which they have for so long a time squatted; but that must not deter him from performing his duty to mankind in declaring a part of this field to be his own.

The Department of Genetics of the Institution affords an unusually advantageous setting for research in human genetics. It is in constant

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touch with the revelations of animal and plant breeding, of cytological research, of bio-chemical analysis. It is thus in a position to make use of interpretations based on such researches. Thus, may be cited the revelations of the work on mouse breeding. This has thrown light on intra-uterine deaths, by which the race is early purified of its most inferior zygotic combinations. The experiments on mice and on daphnids have made still clearer the consequences of inbreeding; and its potentialities for race regeneration. Mice and pigeons have thrown much light on the origin and meaning of certain developmental defects that are found also in man. Especially illuminating have been the researches on dwarfism and leukemia in mice. The work with pigeons is of aid in the interpreting of those endocrine functions that play so important a rôle in human physiology and disease. The work on plant variegation throws light on all development, including that of man. The observation of irregularities in the chromosomal complex of Datura may be expected to aid in the interpretation of some abnormalities in human development. Principles discovered in any part of the world of organisms are of wide-spread application.

In another way the Department is advantageously situated for fundamental human studies, and this is because of its relation to other departments of the Institution engaged in related work. It has been happy to assist in the Maya problem by considering the constitution of the Maya Indians of today in their home in Yucatan and the development of their traits. It anticipates with pleasure the opportunity further to cooperate with the Department of Historical Research in its proposed study of eminent families and the rôle they have played in history. It has collaborated intimately with the Department of Nutrition in the study of pigeon metabolism and the human racial differences in basal metabolism and in changes in the rate of basal metabolism at different phases of child development. More and more the human studies in this Department must tie up with those of the Department of Embryology. The interaction of a number of investigators studying the same material, man, from different points of view and with differing techniques is being unusually fruitful of results.

Already the studies on genetics are exerting an influence on the fundamental philosophy of the sociologist and the medical investigator. Some educators are seeing more clearly the fact of innate differences in mental capacity in children. The head of the pathological department of Columbia University, who has been cooperating with us in the mouse leukemia project, has declared, in effect that henceforth pathologists and geneticists must work together. Otologists have subsidized a research into the genetical factors present in otosclerosis. An ophthalmologist has left a fund to be spent largely for research into the heredity of eye defect. A revolution is occurring in medicine; constitution is being recognized widely, as it has always been sporadically, as not less important than *conditions* (including parasites) in the history of any disease. A wide-spread change in point of view is imminent in consequence of which philosophy and sociology more and more will be guided by biological and, especially, genetical discoveries.

DETAILED REPORTS ON CURRENT INVESTIGATIONS

MUTATIONS

DROSOPHILA

It is said that one of the topics with which the ancient Greek philosophers sharpened their wits was: Which came first, the egg or the hen? Some years ago, Bateson concluded that modern genetics had answered that question definitively in that it had demonstrated that it was in the process of maturation of the egg that the new mutation, which was a necessary first step in the formation of a new species, first appeared.

Today we are not so sure about this. Evidence is accumulating that mutations may, and do, occur at various ontogenetic stages in the development of the individual, and in so far as they affect primordial germ cells they may affect the race. One of the clearest cases of this is found in *Drosophila virilis*, as worked out by Demerec. There is a gene that is responsible for a so-called miniature (or miniature-3) wing. Three types of this gene are known, as set forth in earlier reports. These are: α, which mutates both in germ-cells and somatic cells; β, which does not mutate back to the wild type at all; and γ, which mutates only in somatic cells.

Instability of the Gamma Gene

This miniature gamma gene is a sex-linked one; *i.e.* all female flies carry two sets of the gene and all male flies carry one set only. If the gamma gene had the same rate of instability in both sexes, expectation would be that in homozygous females there would be twice as many mosaic (mutated) flies as in the males. But in some thousands of each sex Demerec found that the proportion was the same. On the other hand, the mosaics produced by females heterozygous for miniature gamma and a stable miniature were only half as numerous as those produced by males. These experiments indicate, concludes Demerec, that the rate of instability of the gamma gene is about twice as high in males as in females. Any possible differential influence of the female cytoplasm upon the gene coming from the male was ruled out by the nature of the experiment. Since from females that were homozygous for the gamma gene (with 2 sex-chromosomes affected) about twice as many mosaic flies were found as among females that were heterozygous for the gene (with only 1 sex-chromosome affected), it follows that the rate of instability of the gene is the same in the homozygous and the heterozygous conditions.

In an attempt to find the factors that control the frequency of the somatic mutation of the gamma gene, varying temperature was employed, following the successful attempts of Muller to influence mutation, in general, by this means. From a single batch of fraternal eggs, gamma flies were hatched at 20°, 25°, and 30° C., respectively. From over 10,000 flies, mosaic wings were produced in the following percentages: at 20°, 11.07 ± 0.41; at 25°, 10.98 ± 0.47; at 30°, 9.06 ± 0.35. The flies reared at 30° were smaller and had shorter wings. Since the smaller number of mosaics observed among these flies is probably due to the technical difficulty of detecting minute mosaic regions on small wings, it is evident, Demerec concludes,

that the range of temperature used in this experiment has not affected the stability of the gamma gene.

While external factors are slow to increase the instability of the gamma gene, there are internal factors that do so regularly. Last year were described three modifying genes which increase the somatic instability of the gamma gene. These were called *S-1*, *s-2*, and *S-3*. This year still another has been found; it is called *S-4*. This gene stimulates somatic instability of the alpha and gamma genes and also makes these genes unstable at an earlier stage in ontogeny.

Demerec finds that gamma and alpha flies carrying the *S-4* gene have mosaic wings; *i.e.* wings that have mutated back to the wild type in spots. Among these mosaics a few are found with one wing of the wild type and the other wing either miniature or mosaic. Until *S-4* became known, mosaics of such type had never been observed. These mosaics indicate that the change from miniature to wild type occurs early in ontogeny; in other words, the miniature-3 gene under the influence of *S-4* becomes unstable at stages of ontogenetic development at which previously it had always been found to be stable. As mentioned in last year's report both miniature-3-alpha and miniature-3-gamma are stable during the first eight nuclear divisions following fertilization (otherwise we would have flies at least one of whose wings would be normal, or wild-type, and some of whose germ-cells would be wild-type). After these eight divisions the germ cells separate from the somatic cells. Thereafter the alpha gene becomes unstable both in somatic and germinal tissue and the gamma gene in somatic tissue only. Experiments indicate that *S-4* does not influence the stability of the gene during these first eight nuclear divisions but it begins to act only after the separation of the germinal tissue is accomplished. Probably *S-4* originated in our cultures. It was not until the line in which it arose had been under observation for 38 generations that the mosaics characteristic of *S-4* were first noticed. Demerec reports further:

"*S-4* is a simple Mendelian dominant. Except for the stimulating action on the miniature-3 gene, no other effect has been noticed to be due to *S-4*. Since the *S-4* acts as a strong stimulating agent upon the instability of miniature-3, practically all flies carrying that gene have mosaic wings, usually showing several wild-type spots. It is, therefore, a simple matter to distinguish flies carrying *S-4* from those having its wild-type allelomorph. In families segregating for *S-4*, ratios agreeing closely with expectancy are obtained."

The instability modifiers are genes having a variety of locations in the chromosomes. Thus it has been found that *S-1* is located in the right end of the second chromosome, 30.6 units toward the right of rounded; *s-2* was found to be located in the fifth chromosome. *S-4* is not located in the second, third, fourth nor sixth chromosome; it is, therefore, probably in the fifth. This hypothesis is being tested.

Crossing-over in the X-chromosomes of Drosophila virilis

The genes are distributed along the chromosomes at definite, but unequal, intervals. A crossing-over takes place between the genes of homologous chromosomes and such crossing-over is more frequent the farther apart

the genes. Based on the totals of the crossing-over between pairs of genes, one computes the total "genetic length" of the chromosome. The genetic length of the X-chromosome of *D. virilis* indicates that crossing-over occurs in this species with higher frequency than in *D. melanogaster;* this problem was accordingly investigated. The results are shown in the chromosome map of figure 1. This lists the factors used in the experiment and gives their location. The 4 factors placed above the line in the figure came from one parent; the 4 below from the other parent.

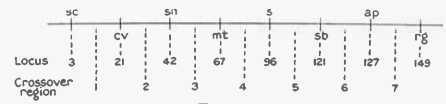


FIG. 1

As expected, crossing-over was found to occur with unusual frequency. This appears from a comparison of the percentage frequency of single cross-overs and multiple cross-overs of various degrees, as given below. The data for *melanogaster,* introduced for comparison, are as summarized by Anderson and Rhoades.

Total percentage occurrence of different multiples of cross-overs

	Number of flies	Multiples of cross-overs					
		0	1	2	3	4	5
virilis	1890	16.98	37.67	28.04	12.65	4.29	0.37
melanogaster	26908	45.95	46.24	7.64	0.17	0.0074	

Thus, while very few cross-overs involving 4 regions were observed in *melanogaster* and none involving 5 regions was found among 26,908 flies, such cross-overs are frequent in *virilis.* Even cross-overs in 6 regions may be expected when the numbers become larger.

"Coincidence between observed and expected crossing-over in any two regions was found to be high. Coincidence was generally higher for the adjacent regions located farther apart. Coincidence for regions 4 and 1 is 0.64; 4 and 2 is 0.95; 4 and 3 is 1.05; 4 and 5 is 1.21; 4 and 6 is 0.80; and 4 and 7 is 0.73. Similarly coincidence for regions 5 and 1 is 0.37; 5 and 2 is 0.40; 5 and 3 is 0.46; 5 and 4 is 1.21; 5 and 6 is 1.48; and 5 and 7 is 0.52."

Finally, the percentage of cross-overs in the different regions that are single cross-overs is variable. Thus, this percentage is in region 1, 19.1 per cent; in region 2, 25 per cent; in region 3, 30 per cent; in region 4, 23 per cent; in region 5, 29 per cent; in region 6, 6.5 per cent, and in region 7, 27.8 per cent. Region 6 being one with low percentage of single cross-overs must have a large proportion of multiple cross-overs.

MINIATURE-3-ALPHA, BETA AND GAMMA ARE MULTIPLE ALLELOMORPHS

The fact of the existence of three different genes occupying (in different individuals) the same locus in the chromosome has been often noted before

and constitutes the phenomenon of multiple allelomorphism. This phenomenon has not received the attention it deserves, since it is possible through it to obtain a deeper insight into the nature of the gene and indeed of the organic molecule, in general. Correns in 1919 has, indeed, considered it as evidence that, with the great central molecule of the gene, atom groups were associated; atom groups that could be withdrawn from, or added to, the central molecule, thus altering its qualities without disturbing its location. Eyster and Demerec have thought of the gene as composed of more elementary units (genels, of Bridges) and Thompson has recently urged his side-chain theory of the structure of the gene, according to which atoms or ions may be added to, or subtracted from, the main body of the nucleus without altering the locus of the gene, but permitting a graduated change in its qualities, according to the amount of change in the elements of the side chain. The systematic study of multiple allelomorphism, as a means of analyzing the organic molecule, is much to be desired.

Change in Dominance in the Ruffled Gene

Mr. G. A. Lebedeff discovered that the fifth chromosome recessive gene, ruffled, becomes dominant when together with the second chromosome dominant gene, rounded. In addition to a change in dominance these two genes interact in such a way that a new character "roofed wings" appears. He found also that a similar relationship exists between ruffled and the sixth chromosome dominant gene, clipped. Rounded and clipped are similar in effect, they both affect the shape of the wings. Tests made with other genes affecting wings revealed the usual relationship between ruffled and these genes.

New Characters in Drosophila virilis

For the use of other geneticists, the following list of mutants recently discovered in *D. virilis* by Demerec and associates is herewith made of record.

"Characters found recently in *Drosophila virilis* are the following: maroon (*mr*) eye color, sex-linked recessive, located 3.3 units from forked and 4.6 units from miniature; plum (*pl*) eye color, sex-linked recessive located in the neighborhood of small bristles; puffed (*Pu*) eye texture, second chromosome, dominant, located 26.4 units to the right of confluent; short veins (*sv*), third chromosome recessive, located 24.8 units from telescoped and 23.5 from garnet; cardinal (*cd*), light eye color, third chromosome recessive, located one unit from garnet; reduced (*Rd*) veins, fourth chromosome dominant, giving no crossing over with glossy among 2968 flies; peach (*pe*), recessive eye color; the first locus at the left side of the fifth chromosome; short vein fifth (*Sv-5*), fifth chromosome dominant, located 46.4 units from peach and 29.3 from interrupted; wingless (*wl*), fifth chromosome recessive; clipped (*Cl*) wings, sixth chromosome dominant."

DATURA

Gene mutations, by virtue of which new hereditary characters are introduced into a species, have a frequency of occurrence that is directly proportional to the time and thoroughness of the search made for them. In general, there are three methods relied on to secure them. First, the

method of extensive collection of individuals, or seeds, over as wide an area as possible, or through the intensive collection of individuals over a smaller area. By the latter method, Shull, years ago, collected at Cold Spring Harbor some scores of biotypes of shepherd's purse, previously quite unrecognized. Second, the method of breeding horticulturally great numbers of individuals and examining and comparing them closely. This has been the favorite method of the great plant breeders; for example, Burbank, who each year raised many thousand ("millions," he called them) individuals of the species in which he was, at the time, interested. Third, the method of inducing gene mutations by the use, at present, of X-rays and radium. But this method results also in chromosomal changes.

It is now 13 years since this Department entered seriously into the Datura problem. Although *Datura stramonium* had been much worked with by the early hybridizers, had been used by De Vries in his studies leading to the re-discovery of Mendel's law and had formed the basis of an extended report to the Evolution Committee by Bateson and his collaborators, only two Mendelian character pairs were known in this species when the Department began its genetic investigation of Datura. All told, there have appeared in Blakeslee's cultures over 160 characters that are provisionally classified as genes. A few of the groups may be mentioned. There are 20 albinos, one of which has been located in the 13 half of the 13·14 chromosome. These albinos, like other types that die in the seed pan, generally must be bred in the heterozygous condition, though with great difficulty some may be grafted and used homozygous. A near albino that is able to survive in the seed pan and grow further is called pale. We have 15 pales of which two have been located, one in the 21·22 (Gl) chromosome and the other in the 15·16 (Rd) chromosome.

Five different kinds of male-sterile mutants have turned up. One of these, a dominant, has been located in the 9·10 (Ec) chromosome by two methods. Since this MS-1 has no pollen it could not be used as male in crosses. Consequently it was used as female in crosses to certain prime types used as pollen testers. Crossed with prime types in which the 9·10 (Ec) chromosome is present and interchanged with another, and only in such, and the female offspring back-crossed to Line 1, plants with 50 per cent bad pollen resulted. Hence it is concluded that MS-1 is located in the 9·10 chromosome. Again, a MS-1 plant was found by Blakeslee to have mutated to a tetraploid. This female crossed to a 2n gave a male-sterile 3n. A female of the latter back-crossed to 2n gave some male-sterile 2n + 9·10 (Ec) plants, as well as other primaries. Such 2n + 9·10 plants produced in their offspring trisomic ratios for male-sterile, thus again demonstrating that the male-sterile gene lies in the 9·10 chromosome. Of the remaining 4 recessives, 2 are female-sterile.

Abortion of half the pollen grains without abortion of the egg-cells is known in 9 cases and is probably due to genes lethal only to the pollen grains affected. These genes are called half-male-sterile (HS). HS-1, discovered in a race from Japan, has been located in the 19·20 chromosome by means of crosses with PT 7 and PT 8. Hs-4, apparently, is in the 3·4 (Gs) chromosome, since it appears to be linked with bronze which is in this chromosome.

A group called rough, or glaucous, from the appearance of the leaves, is made up of 8 types. One of these behaves as a dominant character, linked with a chromosomal complex due to translocation between the 1·2 and the 11·12 chromosomes. However, the possibility must not be overlooked that in this, as in some other cases, the morphological effects may be attributed to chromosomal excess, or deficiency, rather than to a single gene linked to a chromosome of the new complex.

We have 15 or 16 types involving pollen form, or behavior, which are classified as due to genes. A recessive (Baltimore bad) located in the 21·22 (Gl) chromosome inhibits conjugation of chromosomes at meiosis. A recessive that is probably in the 19·20 chromosome was isolated in a race from Hungary; it causes doubling and twinning of chromosomes at meiosis, leading to giant pollen grains containing as many as 96 chromosomes. A recessive discovered by S. Horowitz last summer, from X-rayed material, produces giant pollen grains through dyad, instead of the usual tetrad, formation. Another type has half of the pollen grains without starch; the gene for the light grains is not transmitted through the pollen. Still other types have compound grains, bean-shaped grains, grains with premature germination, etc. Finally, into a miscellaneous group Blakeslee puts some 90 or more types of which the majority at least are probably to be classed as due to genes. The genes, as isolated, serve as markers for chromosomes and parts of chromosomes.

Prime Types (PT's)

These have been defined in the last Year Book as chromosomal 2n races, which are homozygous for one or more interchanged, or translocated, chromosomes. Up to the present, Blakeslee, Bergner and collaborators have discovered 57 prime types; and in 33 of these the modified chromosomes have been already determined. Among these are chromosomal testers for all of the chromosomes except one. Indeed, translocations and interchanges are so frequent in radiated material that economy is now necessary in their isolation. Some induce 25 per cent or 50 per cent aborted pollen when heterozygous. These can be isolated by pollen determinations and the tedium of cytological study avoided. Once isolated, the chromosomes involved may be determined by cytological study of hybrids with appropriate chromosomal testers. By use of compensating types, pollen testers or genes, the chromosomes involved can be determined entirely without cytological work. Prime types are of value as chromosome and pollen testers and as source of tertiary (2n + 1) types and of compensating types. Of especial interest is the possibility which a large collection of prime types affords of synthesizing new pure-breeding types.

Synthesized Pure-Breeding Types

The late William Bateson used to emphasize the point that modern genetics was not throwing light upon the origin of species. The new knowledge concerning segmental interchange between chromosomes does have bearing on that matter. As Blakeslee has pointed out, the most satisfactory criterion of a species would be morphological distinctness from other species in respect to more than a single character and a degree of

constancy in reproduction. The 2n + 1 chromosomes lack the element of constancy. The prime types and certain other chromosomal types, on the other hand, do breed true and might become the progenitors of synthesized pure-breeding types. Blakeslee's group of investigators has made most progress with the 1·2 chromosome and they have obtained homozygous types similar in appearance to the secondary 2n + 2·2, which has extra ·2 halves. Success depends upon the fact that the extra ·2 half, one or both, can be transmitted through the male.

The first pure-breeding type has 24 chromosomes and is homozygous for the chromosome 2·11·12, in which the ·2 fragment is permanently attached to the 11·12 chromosome. It has bred true for several generations. The second type is a compensating type with 26 chromosomes homozygous for the secondary chromosome 2·2 and for the fragment ·1. The third type resembles in appearance the other two types. It has 26 chromosomes and is homozygous for the modified chromosomes 2·14 + 13·23 + ·24. It should breed true. It seems probable that, in time, other pure-breeding chromosomal types may be synthesized. Though these laboratory species are artificial, they render it not improbable that their counterpart may some time be found in nature.

Species in Nature

The possibility that species may have arisen in nature by the same processes as have produced our artificial species is supported by the analytical study of chromosomal differences in Datura, both from the standpoint of intraspecific and interspecific differences. These studies have been made by Dorothy Bergner.

Intraspecific differences between the races of *Datura stramonium* have been found in a study of about 550 races from nature. Five types have such relation of chromosomes to each other that they are interpreted as having arisen by interchange of segments between chromosomes. It is indeed probable that such segmental interchange is of widespread occurrence.

Interspecific chromosomal differences have been further studied. It is now possible to state the differences in the ends of chromosomes in the 3 related species. *D. stramonium*, *D. quercifolia* and *D. ferox*, in terms of the races used as standard testers. Remembering that in our standard species (*D. stramonium*) the chromosome halves are numbered: 1·2, 3·4. . . . . 23·24. for the 12 chromosomes. one sees what new combinations of part chromosomes have been made in other feral species. Thus both *D. quercifolia* and *D. ferox* have the chromosomes 1·18. 2·17, $11 \cdot 21^{21}$ and $^{12}12 \cdot 22$ instead of the stramonium chromosomes 1·2, 17·18, $11 \cdot 12^{12}$ and $^{21}21 \cdot 22$ (the super-numbers indicating humps or satellites). *Quercifolia* has the chromosomes $7 \cdot 20^{20}$ and $19 \cdot 8^{8}$ and *ferox* the chromosomes $7 \cdot 20^{16}$ and $15 \cdot 16^{20}$ instead of the stramonium chromosomes $7 \cdot 8^{8}$, $19 \cdot 20^{20}$, and $15 \cdot 16^{16}$.

When these species are crossed *inter se*, new chromosomes are sometimes formed by segmental interchange. Thus in the *stramonium-ferox* hybrid the two new chromosomes, $7 \cdot 20^{20}$ and $19 \cdot 20^{16}$ are obtained. *D. leichhardtii*

has been crossed with *D. stramonium, D. innoxia, meteloides* and *pruinosa*. So far chromosomal configurations apparently due to segmental interchange have been found in 8 different *inter se* hybrids in Datura. Segmental interchange has, therefore, probably taken place in the differentiation of these species.

Pollen-tube Growth

Dr. John T. Buchholz has continued his study of pollen-tube growth. He finds that there are certain recessive genes which delay pollen-tube growth. In consequence these types can not ordinarily appear in the homozygous condition. By limiting the number of pollen grains placed at one time on the stigma, he has been able in one case to obtain plants homozygous for the slow-growing tubes. They constitute a morphologically distinct and novel form. In combination with C. C. Doak he has devised a still more effective method of securing the transmission of these recessive genes. This method consists of cutting out the portion of the style containing the most advanced normal tubes and grafting on the upper part of the style which contains the slow-growing tubes. The latter were thereupon found to function despite the surgical operation.

Tissue Changes in Chromosomal Mutants

With the assistance of Helen Houghtaling, Dr. E. W. Sinnott has been carrying forward his study of the tissue changes induced by extra primary and secondary chromosomes. By plotting the + and − deviations from the condition in normal 2n plants, for some 30 different tissue characters, he finds in some cases that the primary type is intermediate between its two secondaries, as was to have been expected. But in other cases, the primary is more extreme than either of its secondaries. This fact points to complementary factors in the two halves of a single chromosome and brings added evidence for the conclusion that the normal assemblage of genes within the organism intimately interact.

CLADOCERA

Banta has continued, with the assistance of Miss Wood, the study of the mutants that are revealed by inbreeding clones of Cladocera which have long been carried parthenogenetically. These mutants are largely physiological; among these mutants are dwarfs, referred to in last year's report. At that time fertilized eggs had been produced from them. Over 100 hatches have, at the time of the present report, been obtained. The breeding results, so far, are as follows. Dwarfs inbred and crossed have produced 10 viable offspring, all dwarfs. Crossed with normals the 53 F_1 generation comprised only normals. The F_2 inbred were 11 normals and 5 dwarfs; these mated *inter se* produced 14 normals to 5 dwarfs. Despite early mortality and sterility the hatches yielded sufficient number of viable individuals to support the conclusion that dwarfness is recessive and that a single, principal genetic factor is involved. There are, however, probably accessory factors influencing dwarfness and there is the further complication of slow developers that are not dwarfs.

DETERMINATION OF SEX

CONTROL OF SEX IN MOINA MACROCOPA

For many years, now, Banta and Brown have been trying to get a satisfactory explanation of the fact that the daphnid, *Moina*, produces males when they are crowded in the bottle; and they have drawn Dr. C. A. Stuart of Brown University into the problem. Stuart was inclined to think of the experiment in terms of nutrition—the more mothers per bottle the less food for each. To test this view, a homogeneous bacterial suspension was made up and from it 4 different dilutions, *viz*, 1/15, 1/25, 1/50, 1/100. Each of these 4 dilutions is then placed in 4 similar bottles, the volume of the fluid in each varying but the total bacteria remaining the same. The same number of daphnids is placed in each bottle, and each daphnid has the same absolute amount of food (though in varying dilution). In the sum total of the 4 bottles of each dilution the daphnids produced on the average about 35 per cent males, but if we consider the average male production in the 4 bottles of each of the 4 different volumes the result is very different. As the volume increases the proportion of males increases. At the 1/15 dilution the increase with volume was from 11 per cent to 62 per cent; at 1/25, from 24 per cent to 53 per cent; at 1/50 from 4 per cent to 61 per cent; and at 1/100 dilution from 17 per cent to 44 per cent males. Thus, volume is quite as important a factor as total number of bacteria available as food, or even their concentration.

The second type of food and crowding experiment was run in duplicate. In one series the food concentration was low; in the other high. At each food level the mothers were crowded in different degrees. In each series the proportion of males increased with the crowding—there was control of sex by crowding. On the other hand there was somewhat increased male production in the low food-concentration. Thus:

No. of mothers per vial	Per cent male, higher food	Per cent male, lower food
1	0	0
2	9	35
4	35	42
6	41	50
8	51	61

This shows, also, the limiting effect of food concentration.

Banta is inclined to conclude that the amount of available food and the temperature, as reported last year, constitute general or limiting factors. Thus *Moina* mothers will ordinarily produce only males below, or above, a certain number of bacteria per ml. As for temperature, there are two temperature intervals that favor male production. Given food concentration and temperature favorable to male production, then the percentage of males produced is proportional to the amount of crowding.

CRITICAL PERIOD FOR SEX CONTROL IN M. MACROCOPA

While earlier studies by Banta and Brown indicated that 4 hours before egg-laying was the critical point at which sex was determined by environ-

mental factors, yet they later showed (Year Book, 1931, p. 53) that temperature had a larger effect, if applied for longer periods of the pre-adult life of the female. Recently Banta and Stuart have found that the effect of low food-concentration applied temporarily as much as 9 to 14 hours before egg-laying, followed by high food-concentration, will still show itself by high male production. It is thought that the longer continuation of the low temperature helps to build up a male-inducing situation within the ovarian egg and that it takes a prolonged abundance of food to overcome the effects of the earlier scarcity, which had affected the ovarian eggs in a male-inducing direction. The critical period for the *internal* environment (that of the egg itself) is probably 4 hours before ovulation.

THE SIGNIFICANCE OF SEXUAL EGGS IN CLADOCERA

Sexual eggs not only, by their high resistance, bridge over unfavorable conditions in the environment, but produce new genetic combinations, of which some have an especial, survival value, like the thermal clone and clones possessed with exceptionally high vigor and reproductive capacity. Banta has some general ideas on this subject, the outgrowth of his 22 years' experience with the Cladocera.

"Long-continued parthenogenesis results not only in the accumulation within a clone of recessive mutations but also (tho infrequently) in the occurrence of dominant, or partially dominant, mutations. The excavated head and other morphological characters are such. Further (and not too infrequently) a clone after a period of parthenogenesis may suddenly (or progressively) show lessened vigor. Such a clone may ultimately 'recover' its former vigor. More often, however, the lessened vigor persists, or increases, and the clone ultimately dies out, or is discarded as an unsatisfactory line. Such permanent loss of vigor, it seems to us, is most logically explained as due to a semi-lethal mutation which is semi-dominant, or dominant. Many clones of *Daphnia longispina* (which is our Cladoceran species in which mutations seem most common) and some other clones have sooner or later shown evidence of such mutations.

"In the wild, a mutating Cladocera stock might readily perish but for the occasional occurrence of sexual reproduction and the resulting favorable re-combinations. Doubtless, too, the 'rejuvenation' of protozoa by conjugation, or endomixis, is a similar phenomenon.

"The *Moina macrocopa* sexual eggs which promptly hatch (as just described) might readily produce some genetic re-combinations better adapted than the old parthenogenetically reproducing stock to continue the species in the habitat in which sexual reproduction was occurring."

A MODIFICATION OF GAMOGENESIS IN MOINA AFFINIS

Usually a pair of sexual eggs is formed, one in each ovary. Miss Wood has, however, found a strain of *Moina affinis*, from Indiana, which produces at a time only a single sexual egg. If a male is present and fertilization takes place the sexual egg is soon laid; otherwise, it degenerates in the brood chamber. In the latter case there may develop in the opposite ovary from that furnishing the sexual egg and in the same instar some parthenogenetic eggs. In lines where a sexual egg is produced in each ovary, parthenogenetic eggs do not begin to develop until the following instar.

TIME OF EGG-LAYING AND LENGTH OF THE EMBRYONIC PERIOD

The time elapsing between generations is in *Moina macrocopa* about 10,000 minutes. A statistical study shows that mothers that produce females lay their first clutch of eggs, on the average, 11.77 ± 1.68 minutes later than mothers that produce males. The length of the embryonic period is 24.33 ± 2.06 minutes longer for male than female embryos. Thus, on the average, the mother which is giving birth to her first clutch of male young is about 12 minutes older than the mother producing her first clutch of female offspring.

THE TECHNIQUE OF SECURING AND HATCHING SEXUAL EGGS OF DAPHNIA LONGISPINA

Until a few years ago the sexual egg of Cladocera was a somewhat uncommonly noted phenomenon and its hatching was regarded as fairly rare. Miss Wood has developed a successful technique for securing and hatching them in the laboratory. Of 13,450 eggs secured so far from controlled matings during the eight years the work has been in progress, 2630 have hatched.

The problem of securing the sexual eggs involves not only inducing their production but also securing their fertilization at the proper time by males of the desired pedigree whose production must also be controlled. The technique was to place 15 to 18 newly released females at room temperature in 180 c.c. of manure infusion, adding a little more of the infusion after 5 to 7 days. Males and sexual eggs are produced; the latter being fertilized by the males. The sexual eggs must be dried before they will hatch. After 10, and again at 20, days dilute, filtered medium is added. However, as stated in last year's report there are clones of *Moina macrocopa* that hatch without a latent period. These resemble the grasshopper eggs that Bodine found able to hatch without a resting stage and which were accordingly adapted to continue the species in mild climates.

THE RÔLE OF THE ENDOCRINES IN DEVELOPMENT

MICE

Studies reported earlier by MacDowell have shown that dwarf mice have rudimentary, or highly defective, anterior pituitaries, thyroids, adrenals and gonads. Also, last year evidence was found that the pituitary control of the thyroid was primary and irreversible. As a further test of this conclusion a biological assay has been made of the anterior lobe of the pituitary in dwarfs whose growth had responded to thyroid feeding. First, Mr. T. Laanes fed thyroid to 30 dwarf mice, which, after 20 weeks, had attained the weight of 20 to 35 grams. Thereupon Professor P. E. Smith, who is collaborating in these experiments, transplanted the pituitaries of these growing dwarfs into a single, previously untreated, dwarf at the rate of two pituitaries per day. As controls for this experiment, one dwarf brother was treated with one normal anterior lobe a day; another dwarf brother was treated daily with anterior lobes from 4 untreated dwarfs, and a fourth dwarf brother was held entirely without treatment in the same cage. The failure of growth from treatment with glands of the thyroid-fed dwarfs indicates the failure of the thyroid extract to stimulate the produc-

tion of the growth hormones, while the failure to respond to the intensive treatment with untreated dwarf glands adds further evidence for the conclusion that the growth hormone, if not entirely absent, is extremely deficient.

A remarkable outcome of the treatment of dwarf mice with normal anterior lobes is that, even 8 months after treatment is suspended, the dwarf, although never reaching full size, is fertile and sires large litters.

Dwarfs have been used by Laanes in a test of treatment with a highly purified, crystalline extract of the adrenal cortex, prepared and supplied by Dr. R. L. Zwemer of the College of Physicians and Surgeons. Contrary to all expectations, a very carefully controlled experiment, based on 9 dwarfs treated three times a day for a month, gave entirely negative results.

PIGEONS

A Third Hormone of the Anterior Pituitary

It becomes constantly clearer that, in the higher animals, the genes do their work in part by directing the development of organs that direct the later stages of development. This mechanism appears most plainly in the endocrine organs; and the endocrine organs do their work through the hormones that they elaborate and send out into the blood stream to play particular rôles in metabolism and development.

This year two capital discoveries have been made concerning the rôle played by certain hormones secreted by the anterior pituitary gland. From this gland was first obtained, in 1921, by Evans and Long, a "growth" hormone; and a "maturity" or "gonad stimulating" hormone was identified in this gland by P. E. Smith and by Zondek and Aschheim in 1926. It had also been shown that the anterior pituitary secretion is necessary to the stimulation of the mammary gland to produce milk. Next, as reported last year, Riddle and Braucher showed that the development of the crop glands, with crop-milk formation, in pigeons, depends on something produced in the anterior pituitary gland. Riddle, Bates and Dykshorn have now isolated a third distinct hormone from this gland and this they call prolactin. In birds it is the special agent that induces crop-gland formation and its active functioning.

The demonstration of this conclusion rests on a series of intra-muscular injections of anterior pituitary preparations into ring-doves and pigeons. A good type of "growth" hormone, given at the rate of about 0.4 c.c. a day, produced no increase of the crop gland from the quiescent weight of about 100 mg. Also the pure gonad stimulating principle shows no effect. Doses of "antuitrin" (anterior lobe) have no effect, but prolactin has a powerful effect, increasing the weight of a single crop gland to 900 or 1000 mg. At the same time the testes do not respond at all, as they do to the maturity hormone.

After this discovery it was natural to apply it to mammals also, to see if prolactin is the hormone responsible for stimulating milk secretion in them. Accordingly, prolactin was injected into non-pregnant guinea-pigs and rabbits. After 3 to 5 days they began to lactate. In less mature females and in males, a preliminary treatment with theelin, or progestin, was necessary and, when this was followed by prolactin, milk was secreted after the

lapse of 4 or 5 days. But when purified growth and maturity hormones alone were injected no lactation occurred. Riddle and Bates found, as would be expected, some irregular results, perhaps due to some ovarian hormones.

As the method of preparation of the newly isolated hormone will be of interest to those who may wish to repeat the experiments this is given herewith:

Frozen anterior pituitaries of beef or sheep were ground, defatted with acetone and alcohol and dried. This powder was extracted three times in aqueous medium at a pH of approximately 2.5. The acid extracts were precipitated isoelectrically. The isoelectric precipitate was redissolved and precipitated three to five times to free it of maturity hormone and dried with acetone. About 10 per cent of the original weight of dried powder was thus obtained in an acid-soluble, isoelectric-insoluble form. The injection of slightly less than 1 mg. of this substance on each of 3 or 4 successive days gives a definite response in the crop gland of a dove. The addition (to suspensions) of 0.2 per cent cresol to complete the destruction of the growth principle does not markedly affect the "prolactin."

Crop-Milk

Since crop-milk produces a phenomenally rapid growth of pigeons to which it is fed, attention has been directed to the nutritive, vitaminal and hormonal properties of this substance. At the request of Riddle, two Research Associates of the Institution, Professor Lafayette B. Mendel, of Yale University, and Dr. Hubert B. Vickery, Connecticut Agricultural Experiment Station, have taken up and concluded studies on the vitamin A and B content of crop-milk, supplies of this material having been prepared for them daily at this laboratory by Bates. The results reveal the presence of both vitamins A and B, but not in unusual, or especially significant, amounts.

PHYSIOLOGY OF SEXUAL REPRODUCTION AND DEVELOPMENT

METABOLISM OF DOVES AND PIGEONS

While the genes themselves are rather resistant to the influences of environment they determine the development of the endocrine glands which are decidedly sensitive to environmental conditions. On this point Riddle's studies, done in collaboration with Dr. Benedict, and with the assistance of Mrs. Guinevere C. Smith, are of importance. As a result of 413 measurements made on a single race of common pigeons, some held at 15°, some at 20°, and some at 30°C., and all at various seasons of the year, it appears that the seasonal state of the animal markedly influences the value of the metabolism at whatever environmental temperature this metabolism is measured; the metabolism being highest when the animals have been currently exposed to cold (autumn). In the summer, as the temperature used for the measurement is lowered, this increase in metabolism first becomes marked at below 20°C., while in the cool autumn the increase is more nearly uniform and less per degree in passing from 30° to 15°. Thus the so-called "critical" temperature apparently varies with the seasonal and endocrine state of the animal.

Not only does the metabolism of pigeons change with temperature, but also with the internal states that accompany age. Others have shown that soon after birth the human infant has a relatively low metabolism; while at 4 or 5 years it attains the highest metabolism of the life cycle. In pigeons, our collaborative studies show that, at an age while it is still a cold-blooded animal, there is shortly after hatching a period of low basal metabolism, followed, at about 11 days, by a period of very high metabolism. This confirms an earlier report by Kayser and Ginglinger. It is remarkable and, at present, quite inexplicable that the low metabolism occurs when the pigeon is in a period of most rapid growth and increases for a short period as the growth is slowing down.

This difference in basal metabolism shows itself also in different species. Thus the migratory, cold-avoiding mourning dove has a higher metabolism than have related non-migratory domesticated doves and pigeons. This metabolism appears not to respond to cold weather, contrary to the case of domestic pigeons; and this may be related to their migratory habits, by which they avoid cold weather. This peculiarity of the mourning dove reappears in the hybrids between it and the Zenaida dove (whose metabolism is lower).

STUDIES IN PHYSIOLOGY IN RELATION TO RACE AND SEX

Oxygen Carriers of the Blood

With the assistance of Miss Pela F. Braucher, Riddle has accumulated a large body of data on the variation in the quantity of hemoglobin and red cells in the blood of the two sexes of pigeons in different races and at different seasons. It appears that in both ring doves and in common pigeons the number of erythrocytes (red blood cells) and the amount of hemoglobin per 100 c.c. of blood is greater in the male than in the female at all seasons of the year. Since the oxygen carriers of the blood fluctuate quantitatively with the oxygen demands of the tissues, this greater quantity of oxygen in the male reflects the excess demand of the male tissues over those of the female. These facts are in accordance with the theory, established by Riddle's prolonged researches and those of others, that in the male metabolism takes place faster than in the female, and that this difference is a primary sex difference in egg, embryo and adult.

This theory is further supported by another group of facts. In the pigeon-dove colony were found some 30 birds, with ovaries which at an age months beyond the normal age for the start of egg laying had never begun to discharge eggs. These retarded, or sterile, females showed, on the average, a probably significant excess of hemoglobin and red cells over adult, normally functioning females of the same race—thus resembling males of that race.

The number of erythrocytes and the quantity of hemoglobin in the blood also shows a certain relation to season. Thus, the number of erythrocytes is constantly lowest in summer and highest in autumn, when our pigeons experience their lower external temperatures. Roughly, but not quite so definitely, the same rule holds for quantity of hemoglobin.

Intersexuality in Mourning Dove × Ring-Dove Hybrids

It has long been known that in crosses of pigeons belonging to different families only male offspring develop. The mourning dove and the ring-dove belong to different sub-families. From a mourning dove male and a ring-dove female the hybrids were, in 44 cases, studied in respect to sex. Among 21 dead or killed at hatching 16 were clearly males and 5 had nearly the appearance of females. Of 23 that were reared to maturity, 18 were definitely males. The remaining 5 were alike and of special interest. In each, at the site of the left germ gland (the normal site of the ovary) was a small, discolored, rudimentary degenerate mass, quite devoid of ova, but containing testicular tubules. Each had a small oviduct on the left side. These are interpreted as genetic, but not functional, females. They form a new link in the chain of sex intergrades found in the progeny of wide crosses, of which another link consists of males with left oviducts persisting.

Relative Velocity of Growth in Races of Large and Those of Small Pigeons

Recently, Castle and Gregory have shown that cell multiplication is more rapid in the early embryonic stages of races of large rabbits than of small ones. With the aid of Mr. Donald R. Charles and Mr. George E. Cauthen a comparative study of this problem was made by Riddle on our largest and smallest races of pigeons. The weights of embryos of these different races showed that racial size difference is only very imperfectly expressed during embryonic life. But in the post-hatching period, size difference becomes accentuated by a differential growth rate and practically all of the adult size difference is attained before maturity. Riddle concludes that while it is still uncertain to what extent endocrine (pituitary) differences determine rate of cell-growth at any particular developmental stage it is wholly probable that such endocrine difference is an effective factor in higher animals at some stage.

Riddle, with the assistance of Miss Theodora Nussman, has found that, on the average, female pigeons and ring-doves have both longer intestines and larger anterior pituitary glands than males of the same race, though the females weigh significantly less than the males. This finding supports his view that the pituitary secretion influences length of the intestine. It has been shown by others that in man and rats the pituitaries are larger in females than males; so, this wide-spread pituitary difference may represent a fundamental sex difference.

Chromosomes in Pigeons, Doves and Their Hybrids

The importance of a knowledge of chromosomes for the interpretation of the results of hybridization has led us to seek the cooperation of Professor Robert T. Hance of the University of Pittsburgh in this study. He started work at Cold Spring Harbor and is still continuing his studies at Pittsburgh. Though the difficult task is still unfinished, Dr. Hance has furnished for this report the following statement:

"The chromosomes of 'the pigeon' are greater in number but rather more favorable for study than are those of the domestic fowl. The metaphase

plate shows the chromosomes in much the same size variations as were found in the chick. The number of chromosomes will perhaps always be difficult to determine with accuracy, although the Japanese student, Oguma, reports 62 as the typical male number. My counts on material that is as well preserved as Oguma's have seldom risen much over 50 and in the few cases in which 60, or more, chromosomes were found, fragmentation was rather clearly indicated. As in the case of the chick the male pigeon has two chromosomes longer than the others, while the female has but one of equivalent length. These observations agree with those of Oguma and it seems very likely at present that these longest chromosomes are the ones associated with, if they are not the actual determiners of, sex."

GENETICS OF SPECIAL TRAITS

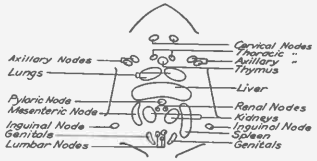
LEUKEMIA IN MICE

Cytological Studies

The cooperative group working under a grant from the Carnegie Corporation of New York on mouse leukemia in this Department and in the Department of Pathology of the College of Physicians and Surgeons in New York has been strengthened by the addition of James S. Potter, a cytologist, at Cold Spring Harbor, and Joseph Victor, a cell physiologist, in New York. In both new fields important discoveries have been made. The cytological studies have established a fundamental basis for the classification of the disease leukemia as a form of cancer.

Studies cited in earlier reports have shown that living cells are required to transmit the disease. But the possibility remained that within the host the inoculated cells transfer some agent responsible for the leukemic phenomena to cells of the host, while they themselves die. In such case the cell lineage of the infiltrating cells, in successive transfers of an inoculation line, would be discontinuous, instead of uninterrupted as is the case with true cancer. If indeed the inoculated cell is the unit, its leukemic properties may be due to changes in the mechanism responsible for all hereditary traits. These cytological studies, as well as the organization of the laboratory for microscopical preparation, have been carried out by Potter, with the assistance of Margaret D. Findlay and Phyllis V. Plyler.

In tracing the origin of the infiltrating cells that follow the inoculation of a susceptible mouse it is necessary, first of all, to establish the identity of the leukemic cells. In a given inoculation line the predominating cells accumulated in all lesions of the inoculated mouse have the same features, but these sometimes are found in normally occurring cells. The only constant difference found was in a precocity of the process of chromosome-splitting before metaphase. There are, however, certain differences between the leukemic cells of the different inoculation lines; for example, between Lines I and L. Thus, in Line I the leukemic cells are large, basophilic, usually irregular and with 30 or more mitochondria. In Line L, on the other hand, such cells are smaller, less basophilic, more rounded. Also, in fields consisting entirely of infiltrations, Line I gives an average of 6.7 per cent of cells in a recognizable phase of division, while Line L gives 3.7 per cent of such cells.



KEY TO DIAGRAM

HOURS AFTER INTRAPERITONEAL INOCULATION

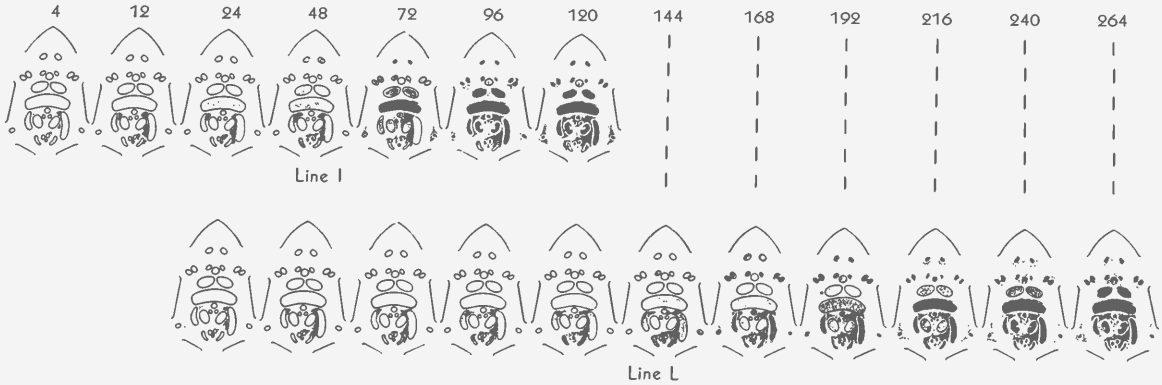


FIG. 2

The second step in tracing the origin of the infiltrating cells was to follow the inoculated cells from the moment of inoculation until the death of the animal. In each of three transfer generations of Lines I and L a series of animals was killed at regular intervals following inoculation, done sometimes intraperitoneally and sometimes into the thigh muscles. In the latter class, the inoculation was confined more closely and its spread more readily traced. For this purpose the nodes and organs of 172 mice were studied in serial sections. Thus the behavior of the inoculated cells was followed step by step and the development of the lesions was observed as in a moving picture. Many of the inoculated cells disintegrate, but many survive, penetrate the host tissues and proliferate by division. Cells of Line I (where cell division is most rapid) are disseminated and establish lesions throughout the host about twice as rapidly as cells of Line L, although the path from a given site of inoculation is the same (fig. 2). The mice inoculated with Line L cells live twice as long as those inoculated with cells of Line I.

The third step was to study the lymphoid tissues of the host to determine whether the germinal centers of these tissues had been stimulated to greater activity and to the production of cells of the type characteristic of the line. No evidence of such activity was found. The descendants of the inoculated cells could be shown to enter the lymph nodes, spleen, etc., and not to originate within them.

Since it is possible to trace the injected cells and their descendants to the formation of lesions and since the lymphoid tissues of the host do not become active in the formation of the type cell, the conclusion is reached by Potter that the cells of a given line form an unbroken lineage of descent from transfer to transfer, that they are direct descendants of the cells taken from the original mouse with spontaneous leukemia that started the transmission line.

Carbohydrate Metabolism

Workers with tumor tissue have demonstrated an increase in aerobic and anaerobic glycolysis in such tissues as compared with normal. Furthermore the difference between malignant tumors and normal tissues is greater than that between benign tumors and normal. An explanation of this altered metabolism has been found to a certain extent by the demonstration of the inability of malignant tumors to oxidize lactic acid. Investigation of the agents that alter metabolism of normal tissues to that of malignant tissues may throw considerable light on the agent concerned in malignant growth.

In view of these important studies, Joseph Victor has undertaken the investigation of the metabolism of leukemic tissues from spontaneous and inoculated cases.

In these experiments the oxygen consumption and aerobic and anaerobic glycolysis were measured by means of the Fenn respirometer. Ringer's solution was used as the bathing medium. In the aerobic experiments the oxygen tension was 95 to 100 per cent, depending upon the presence of CO_2 in the gas. Five per cent CO_2 was used in the glycolysis experiments.

Ninety-five per cent N_2 was used in the anaerobic measurements. The temperature was 37.5°C. ± 0.005°.

Compared with normal lymph nodes, the carbohydrate metabolism of leukemic nodes has a higher oxygen consumption than aerobic and anaerobic glycolysis, which both increase with the chronicity of the disease. The relative increase in metabolism is found to be greatest in the anaerobic glycolysis and least in oxygen consumption. Further experiments will have to decide whether this change with chronicity is due to a physiological change in the leukemic cell or to the increase in their number. Metabolism of leukemic tissue resembles that of benign tumors and approaches that of malignant tumors as the duration of the disease is prolonged. The increased oxygen consumption associated with an increased aerobic lactic acid production suggests that lactic acid may play a rôle in stimulating the respiration of lymphoid tissue or of leukemic lymphoid tissue.

Inheritance of Spontaneous Leukemia

As has been stated previously, the first generation hybrids between the leukemic strain C58 with which MacDowell is working and the non-susceptible strain StoLi show susceptibility to spontaneous leukemia; indeed, over half are leukemic (while in the uncrossed leukemic strain 90 per cent are leukemic). The genetic differential between the two strains that influences the occurrence of leukemia is, accordingly, not a recessive gene. Since in the F_1 generation 56 per cent are leukemic; in the back-cross F_1 x resistant strain, 43 per cent; and in the F_1 x pure leukemic strain, 53 per cent; one must conclude, that there is partial dominance of a complex genetic control interacting with factors not under specific genetic control.

Changes in transmission lines—Six transmission lines have been maintained throughout the year and the number of transfer generations now ranges from 53 in Line L to 203 in Line I. As MacDowell puts it:

"In view of the continuity of cell lineage now demonstrated, these lines may be spoken of as cultures of independent somatic cells that have lived parasitically for periods of 2 to nearly 4 years in the mice successively inoculated. This experience has led to certain general conclusions.

"(1) Characteristically, during the course of the early transfers, the virulence of the disease, judged by the time the hosts die, increases rapidly and then maintains a uniformity over long periods of time. Though they differ in the rate of this increase, all lines tend to become stabilized when the minimum interval till death reaches 7 to 9 days. In a few cases where deaths in the first transfer were unusually rapid, the characteristic increase in virulence did not occur and the later history shows no unusually high virulence.

"(2) Lines that have become stabilized show characteristic degrees of variability in the death intervals of individual hosts in the same transfer generation.

"(3) Lines long showing constant virulence may eventually change their virulence. Thus, Line I was highly uniform during the 16 months in which it was being used for the analysis of the genetics of susceptibility. Subsequently a change has taken place that is expressed in virulence as well as other ways. Death now occurs in 4 to 6 days instead of 6 to 8 days;

the excessive infiltration of the abdominal muscles is something novel. Potter finds the number of mitochondrial cell inclusions to have increased from about 20 to over 30. Furthermore, the cells of this line will now develop in the strain of mice that was previously negative (StoLi), but the interval before death is longer than in strain C58 and some of the animals are able to eliminate the disease after the inoculated cells have undergone considerable growth. Correspondingly, back-crosses and the F_2 generation no longer give evidence of segregation in respect to susceptibility."

The origin of the various characteristics of the cells and of their activities in the different lines and the nature and control of the changes that they show stand out as major problems. MacDowell suggests the hypothesis that they are due to a selective process working upon individual genetic differences between cells.

"The process of injecting suspensions of minced spleen into a mouse at each transfer provides a selective basis. Large numbers of cells die; the descendants of those cells that survive the passage and are best qualified to grow in their new environment will predominate in the host tissues and the succeeding transfer will start with a more uniform and more potent population of cells."

This raises the question of the possibility of genetic variation among the leukemic cells of a spontaneous case. As a test of this possibility a new series of eight parallel lines, started from various tissues of a single spontaneous case, has been carried for six months. On the chance that cells found in a given organ might have a special qualification for the environment of that organ, each line was successively transferred by inoculation with the organ used to start the line. This work is being carried on by Martha J. Taylor. As usual, all lines tend at first to increase in virulence; but differences in the course of this increase appear with a regularity that indicate qualitative differences in different lines. All inoculated mice are being prepared for histological study. So far, two clear-cut physiological differences between two lines have appeared. In the line carried by transfers with the mesenteric node the number of cells in the peripheral blood is regularly several times as high as in any other line. In a line carried by spleen transfers, the late stage of the disease is characterized by extreme anemia.

HEREDITARY EYE DEFECTS IN MICE

Two years ago attention was called to the cross between a certain strain of mice with abnormal eyes and normal mice. This cross produced only normals, suggesting that the eye condition was due to a recessive gene. The analysis has now been carried by Laanes into the second back-cross, by which the classification of the animals in the first back-cross is based on the genotype, or germinal condition, rather than the phenotype, or bodily condition. This test shows that the phenotypic normals and abnormals of the first back-cross are genetically very much alike; though back-crosses to abnormal mothers give a somewhat higher percentage of abnormal young. These results agree with the selection results and prove that the genetic control of this defect is complex. Since many eye defects in man, as well

as mice, are genetically complex this strain of mice should prove especially valuable in the analysis of the developmental processes involved and their interaction with environment.

GENETICS OF THE THOROUGHBRED HORSE

Inheritance of Racing Capacity

Laughlin has continued his study of the genetics of the running horse, with the continued support of Mr. W. J. Salmon. He finds that racing capacity does not yield to a simple Mendelian analysis; that there are not merely 1 or 2 genes that determine success in fast running. This is a somatic quality that depends on the complex inter-action of many genes in the course of individual development.

A definite formula has been worked out for the inheritance of racing capacity which gives a close approximation to the facts. This formula is a machine into which we put the measures of racing capacity for each of a number of the antecedent near-kin, direct and collateral, of a potential foal and from which we get out the probability that this particular foal will, if it races, develop a racing capacity within definite capacity-range. This formula is a very complicated one; it will be quite impracticable to reproduce it here.

The elements in the development of this formula may be briefly considered. Given some 54 horses used as a basis for this work, the futurity index of each is computed, and these indices are arranged in ascending order from left to right. Plotted, they constitute the so-called "ogive" curve; for which a close-fitting formula can be found. Next plot against each prediction value the actual racing value (biological handicap) of each of these 54 horses. By joining these latter values there will result a very sharply and deeply serrated line. But its general trend will make an acute angle with the straightened ogive of the futurity indices. Next a straight line is fitted to these biological handicaps, called the biological handicap fluctuation center. From the straightened ogive of hereditary promises (futurity indices) can now be computed the corresponding fluctuation centers. A table is next made of the per cent deviations of each actual racing capacity from its own fluctuation center; and the mean-square deviation computed for the group. By further treatment of these deviations it becomes possible to predict that, with a given futurity index, the racing capacity of the foal will, by a definite probability, deviate not more than a definite per cent from its own computed biological handicap fluctuation center.

Mathematical Aids to Analysis of Complex Heredity

Laughlin calls attention to the fact that in Thoroughbred horse breeding only the best are saved for breeding. This means that the futurity index of the foals will be very high. In the 42 racing foals of the Salmon Laboratory farm it is 116.1. on the average, and the range of variability is small. But when the actual racing performance of the 42 is considered, the mean index, or biological handicap, is strikingly lower, *viz,* 97.75, and the variability is high. Just because only a highly selected, narrow upper band of

the "independent variable" is dealt with, some other method than the ordinary correlation method of relating anticipation and performance is called for. Laughlin calls his method that of band correlation, or ogive-regression; and he finds the properties and values of this method extremely useful in the present investigation. By this method one can, for example, through a study of a definite upper stratum of the breeding stock selected on the basis of racing capacity, locate by geometric methods the mean of the breed, although the basic data considered may not have covered this region of racing quality. Band correlation also lays the foundation for building a definite formula for the inheritance of racing capacity in the Thoroughbred horse in the manner accomplished by the present study.

Genetic Constitution of the Thoroughbred

The marked discrepancy between the futurity index of an individual and his actual performance has led Laughlin to certain conclusions concerning the "homozygosity" of the Thoroughbred horse. Perhaps no domestic animal is more pure-bred. But within the Thoroughbred breed there are many hereditary differentials—highly significant in racing capacity but relatively insignificant when Thoroughbreds are contrasted with other breeds.

"These differentials are the fine adjustments in heredity. Within this microcosm of fine hereditary differentials all Thoroughbreds are amazingly mongrel in blood. However homogeneous the selected racer may appear, the genotypes are numerous and of varied quality. While mutation must be looked to for radical improvement of the Thoroughbred, there is still much room within every strain of the Thoroughbred to improve greatly by selection among its finely adjusted qualities. For the number of genes involved in racing capacity must be very great."

Results of Inbreeding on Fecundity and on Growth in Sheep

For many years this Department has collaborated with Professor E. G. Ritzman of the New Hampshire Agricultural Experiment Station in a sheep breeding experiment. The attempt to create a new breed by crossing Southdown sires and Rambouillet ewes led to repeated inbreeding through three or four generations. The effect of such long inbreeding on size has been recently studied and the study has yielded some interesting and significant results. It appears that the growth of the lambs during the first 4 months in the later generations was slightly greater than in the first hybrid generation—that in which the maximum of growth is ordinarily expected. The adults of the last generation showed exceptionally large males but the average of the 15 ewes was not increased. Also, during the first three generations of inbreeding, fecundity increased slightly. The key to the improvement lay in rigid selection of the best germ-lines for breeding in each successive generation, selection being made on family performance, rather than on somatic condition. However, in the fourth hybrid generation, in consequence of this selective procedure the flock came to be composed almost entirely of one family line. There is only one best; and inbreeding quickly brings that to the front.

HUMAN GENETICS

INHERITANCE OF MENTAL ABILITY

The evidence is fairly satisfactory that mental capacity, as measured by school progress, is inherited. To that conclusion the work of Dr. H. J. Banker, as reported in the last few Year Books, has added much critical evidence. This has been possible by his invention of the student's ability index (SAI), and its application to the school records of Huntington village. Banker has now compiled data on the scholastic rank attained by parents and children in particular subjects, especially in spelling and arithmetic. The requirements for comparability set by Banker have been so high that the number of available families is small; is indeed reduced to 14 families with 22 children. The results are given in the tables.

TABLE 2—*Distribution of success in spelling of children from selected matings as measured by the subject SAI in Huntington elementary schools*

Types: L=less than 94; M=94–116 inclusive; H=over 116

Type of parental mating	No. of families	No. of children	Children of each type						Average SAI's	
			Total Nos.			Per cent				
			L	M	H	L	M	H	Mid-parents	Children
L X L										
L X M	5	8	2	3	3	25	37½	37½	93.0	106.9
L X H										
M X M	6	8		4	4		50	50	106.2	113.6
M X H	3	6			6			100	118.4	129.2
H X H										
Totals	14	22	2	7	13	9	32	59	104.1	115.4

TABLE 3—*Distribution of success in arithmetic of children from selected matings as measured by the subject SAI in Huntington elementary schools*

Types: L=less than 94; M=94–116 inclusive; H=over 116

Type of parental mating	No. of families	No. of children	Children of each type						Average SAI'S	
			Total Nos.			Per cent				
			L	M	H	L	M	H	Mid-parents	Children
L X L	1	1			1			100	86.0	127.4
L X M	6	10	2	8		20	80		94.9	102.8
L X H	1	3			3			100	109.5	126.1
M X N	5	7		4	3		57	43	101.8	111.1
M X H	1	1			1			100	109.8	132.0
H X H										
Totals	14	22	2	12	8	9	55	36	98.8	110.3

While final conclusions can hardly be drawn from such limited data it does appear that as the special capacity of the mid-parent increases in any subject, that of the average of the children does, in general, increase likewise in the same subject. When the parents are of higher grades in these two subjects the children seem to be more concentrated on high grades, while if the parents are of lower grades, the grades of the children are more dispersed. This suggests, but does not prove, segregation. Peters, also, concluded that there is evidence of Mendelian segregation in special gifts; but his conclusions were based on data less critically gathered, though greater in amount, than those of Banker. This work may be said to add to the cumulative evidence that the mental constitution of the human organism is subject to the same general laws as the strictly physical constitution and is determined in similar degree by genetic factors. Since mentality receives its stimuli and finds its expression through the physical mechanism it is to be expected that it shall be subject to the biological laws of the organism.

HEREDITY OF INVENTIVENESS

Inventiveness is one of the most valuable inborn qualities of a race. In extremes a nation calls for some new device or invention that shall save it from destruction. Unhappy that nation whose population can make no adequate response because of lack of capacity for invention. Laughlin has recently, with the assistance of Edith Banta, sought to find out which of the racial elements of our cosmopolitan population shows the greatest proportions of inventors. In this study each of 7373 patentees, out of all the patentees of the first 10,000 patents issued by the United States in 1927, responded to our request for data on his own Old World race-descent. In each case race-stock was computed in terms of eighths; each patentee giving his own descent as accurately as possible by eighths. These eighths were accumulated regardless of combination in individuals. As index of inventiveness for the particular racial stock in the United States was taken the percentage of the patentees represented by the particular race divided by the percentage of the particular racial stock in the whole population of the United States, on the National Origins basis.

This study gave the following indices of inventiveness by race-descent: French 2.92; Swedish 2.45; Dutch 1.97; Danish 1.89; German 1.65; Norwegian 1.60; Swiss 1.41; Irish 1.11; Scottish 1.08; English 1.01; Welsh 0.90; Australian 0.83; Russian, 0.72; Czechoslovakian 0.60; all others 0.45; Italian 0.40; Polish 0.30; Belgian 0.20; Latin American 0.10; and African 0.03.

INDIVIDUAL DIFFERENCES IN SENSORY THRESHOLDS

Blakeslee continues, as time permits, his studies on individual differences in reaction to various chemicals that give tastes and odors. When phenylthiocarbamide is placed on the tongue, about a third of the population can detect no taste from the dry crystals; but to most they are bitter in various degrees. But even the "non-tasters" got a reaction from a hot saturated solution. Tests of the least concentrations at which the substance is detected (thresholds) show that in a group of individuals taste acuity for this chemical forms a bimodal curve. From a series of comparable tests with 3

bitter substances, phenylthiocarbamide, quinine sulphate, and picric acid, it was shown that an acute taster for one kind of bitter might be a poor taster for another kind of bitter. It was also shown that there is not a close relation between acuteness of taste for any two of the primary tastes—bitter, sour, sweet and salty.

Very striking is the difference in taste category to which the same substance is assigned by different persons. Thus, some find phenylthiocarbamide sour, others sweet, still others salty. Especially common is the inability to differentiate between bitter and sour. To persons with such inability, the terms bitter and sour may denote a quantitative rather than a qualitative difference. Thus, quinine and hydrochloric acid may both be called sour when diluted and bitter when concentrated.

Blakeslee concludes that probably more or less marked differences in respect to taste thresholds for any sapid substance would be found if a sufficiently large number of individuals were tested. Marked differences in reaction were found to the following dry substances: euquinine, quinine sulphate, benzoate of soda (reported by Dr. A. L. Fox), calcium gluconate (reported by F. Thone), creatine (reported by Roger Williams), fumarprotocetraric acid (reported by A. W. Evans). For some of these substances the tasters and for others the non-tasters were the more common. Apparently there is a greater difference between high and low thresholds for bitter than for sour, sweet or salty substances; consequently bitter will probably be better than other tastes in classifying people as to their taste acuity.

As for taste so also for smell, reactors and non-reactors are found to the same substance. This conclusion is based on tests that have been made with the odors of Freesias, *Hemerocallis thunbergii*, Philadelphus, a potted Azalea and other flowers.

THE GENETICAL FACTOR IN OTOSCLEROSIS

By aid of a fund derived from the Carnegie Corporation and coming to us as an appropriation from the Committee on Otosclerosis of the American Otological Society, this Department has been making a study during the past 4 years of heredity of otosclerosis. The first source of our material was the field studies of Dr. Bess Milles, made during 1928 and 1929. Dr. Milles was well trained for this study and had great assistance from Doctors Arthur B. Duel, E. B. Dench, T. J. Harris of New York and Dr. F. E. Shambaugh of Chicago. Additional cases were referred to us by the Volta Bureau.

After Dr. Milles was obliged to relinquish her work, Miss Lillian B. Frink took it up in 1931. She made studies (of members of families that Dr. Milles had begun work upon) in different States of the Mississippi Valley. Later she worked in cooperation with Dr. S. R. Guild at Johns Hopkins Hospital and studied the family history of a number of otosclerotic patients in and about Baltimore.

The results of the field work are found in 60 fairly fully described families. No such carefully and extensively collected data on the distri-

bution of otosclerosis in families has ever been collected in the past; largely because adequate funds had not heretofore been available.

The conclusions from this study have been submitted to the Otological Society for publication. The fact that among otosclerotics over 30 years of age there are nearly twice as many females as males suggested the presence of a sex-linked factor. However, the simplest 10 genetical hypotheses were tested out and the conclusion reached that the hypothesis that otosclerosis is dependent upon two genetical factors, both dominant and one sex-linked, is the most probable. This hypothesis was then applied to the best documented cases and found in no case to be in disaccord with the facts.

COMPARATIVE HUMAN AUXOLOGY

The studies in child development during the second decade have been continued, with the cooperation of Letchworth Village. Starting with 120 children, approximately 60 of each sex, semi-annual observations have been made, namely on the birth month and six months later. The observations are morphological, physiological, psychological, roentgenological, hematological. Miss Frink has made studies of the families, in the field; studies that have led her over the state even to Buffalo. About 40 families have been more or less completely studied. For the different members of a single family 30 to 60 or more schedules have been filled out; a single schedule sometimes involving 80 observations.

To make the measurement taken on the two sexes and on persons of different ages more strictly comparable, standards have been sought for each sex and age and the measurements have been expressed as departures from the standards in terms of the standard deviation. While the correlations between parents and young children are not markedly high, still this basis of comparison seems to be the best available. The standard tables and the correlations have been worked out by Mr. William Drager.

The relation between individual and mass studies of child growth has been studied by the Director. The conclusion seems plain that the curve of growth of children based upon mass statistics has little to do with the way the individual child grows. Growth in the second decade shows one or more marked spurts, which may occur at any age from 12 to 17. The form of the mass curve is determined by the relative frequency of occurrence of the abrupt spurts of growth at different ages.

If in the course of the development of different individuals there are marked differences in velocity of growth, it is to be expected that even greater differences will show in the development of those children that belong to different races of mankind. With this hypothesis in mind, Steggerda has begun a series of studies of individual children. It is planned to observe each at yearly intervals until they are grown up. He has measured the same individual Maya Indian children for two successive years; a group of Dutch children living in Holland, Michigan, is being similarly observed; and it is planned to make parallel studies on a group of as nearly full-blooded Negroes as can be found in our Southern States, and on full-blooded Indians of the Southwestern States. Only by such studies can be seen how adult racial differential characters come into being.

RACIAL PHYSICAL DIFFERENCES BETWEEN INDIANS, NEGROES AND DUTCH

The purpose of anthropometry is to give quantitative expression to the obvious physical differences of the races of mankind. For the most part the data on the physical status of the different races of mankind have been collected by different persons, with more or less differing techniques and usually with very little acquaintance with the history of the individuals they measure and little or no knowledge of their families. In taking up anthropometric work, Steggerda has had the advantage of training in genetics that leads him to make his anthropometric studies on a genetic, familial basis. He has had also the advantage of collecting data himself on the three principal races of mankind—the Negro, the Mongoloamerindian and the European. During the past year he has completed a study of the Maya Indians of Yucatan, from the physical side. These Indians have an exceptionally short stature, very short as compared with Negroes of Jamaica and the Dutch. The relative span of the Indian, although not so great as that of the Negro, is still significantly greater than that of the Whites. The relative chest girth of the Mayas is astonishingly great, being about 57 per cent of stature, while in the Negroes this ratio is about 50 per cent and in the Dutch about 54 per cent.

The Indian has also a relatively long trunk and short legs. Thus his relative sitting height is 53 per cent as compared with 51.5 per cent in the case of the Negroes. The Maya Indian has broad shoulders, his shoulder breadth equalling those of the Plains Indians, who are considerably taller. Other striking traits of the Maya Indians as contrasted with Negroes are: broader pelvis; shorter arms, but relatively longer distal segment of the arm; broader, shorter head; broader face; narrower nose; longer, narrower ears; and more resistant teeth. Three of the average measurements differed somewhat from those obtained by G. D. Williams, who also measured the Mayas. These differences are attributed to slight differences in technique; and to the probability of more white blood in the Mayas measured by Williams.

Mutation among American Indians

The American Indian is far from being a morphologically single homogeneous race; on the contrary, in the course of the post-glacial period during which it has occupied this continent, it has undergone a great number of mutations. Steggerda has plotted the distribution of some of these. Starting from the Great Plateau region, the Indians fall off in stature as one goes southward and increase in stature as one goes eastward. A stream of brachycephalism extends from Alaska to Panama. In the northeastern part of the continent the skulls become more dolichocephalic.

Metabolism among the Mayas

After having measured basal metabolism among the Negroes of Jamaica, Steggerda was especially qualified to cooperate with Dr. F. G. Benedict of the Nutrition Laboratory in measuring the metabolism of the Mayas. This he did and found it to be 8 per cent higher than the norms of Whites, while the pulse rate, taken in a state of complete repose, was found to be on the average 52 per minute, or 9 less than the average for Whites. There seems to be little doubt, consequently, that the races of mankind show differences in basal metabolism, as Benedict concludes. Riddle has argued that the

high basal metabolism of the Maya may be due to the slight amount of clothing worn by them even in cold weather. And it is true that the Maya Indians, in general, sleep in hammocks, covered only by the scant cotton clothing they wear during the heat of the day, though the temperature may fall, during the winter months, to 5° C. above zero. However, some of the basal metabolisms taken by Williams were made in May, when the weather is warm even at night; and such also show the high rate.

Food of the Maya Indians

As an investigation supplementary to that on basal metabolism, Steggerda undertook to secure for Dr. Benedict samples of food used by the Maya Indians. About 65 food samples were gathered and preserved and, in addition, a like sample of the food eaten by four Maya men for three successive days was preserved and sent on to Boston for analysis.

Family Analysis

While the Eugenics Record Office has records of about 25,000 families each systematically described by some member of the family, the average number of persons adequately described in each is small, probably not averaging over 17 persons. Steggerda has recently presented to the Office certain manuscript records of the Steggerda family and the families with which it has intermarried. In the entire study there are involved 963 individuals, of whom about one-quarter have been studied anthropometrically, each yielding from 25 to 50 physical measurements. The work has been done intermittently during the past 10 years. Two studies have been recently published, made on this material. In the first, the data include the birth weights of 48 individuals, and the high sex ratio of 110, based on 432 individuals. Familial causes of death are tuberculosis and cancer. Differing traits of personality characterize different lines; but in each line there is a strikingly high proportion of one trait, such as humor, generosity, craftsmanship.

The second completed study is called, "Physical Measurements in Dutch Men and Women." The results have been discussed above in considering the Maya Indian material.

Race Differences in Hands and Fingers

From a comparative study of the hands of Dutch, Negroes and Maya Indians, Steggerda finds them largest in the Whites; and smallest in the Mayas. But the Indians have the relatively broadest and shortest hands; while those of the Negroes are shortest. From a study of each individual finger the conclusion is drawn that the fingers are more nearly alike in the two sexes in the Negroes than in the other two groups. Also the difference in length between digits IV and II is greatest in the Indians; between III and II is least in the Whites and between III and IV is least in the Indians.

GENETIC CONSTITUTION OF AMERICAN POPULATION

Eugenical Sterilization

The Eugenics Record continues to be called upon for advice on the legislative, judicial and administrative aspects of eugenical sterilization. This makes it necessary to keep in touch with the working out of sterilization

laws. Laughlin finds that up to December 1, 1931, a total of 15,151 persons have been sterilized in 30 different states under the eugenical statutes since their beginning in 1907. Twenty-seven states still have eugenical sterilization laws. Currently, the laws which are being tested by the courts are being quite uniformly upheld as constitutional, in contrast with earlier findings. This change has been due largely to the elimination of the therapeutic and punitive factors in the statutes, so that the state's motive in its enactment becomes emphasized as purely eugenical.

Laughlin finds that the standards for sterilization are so conservative that there has been no complaint that any state has lost valuable breeding stock. Meanwhile, the states are gaining valuable experience in eugenical sterilization—the legislators in defining the legal standards of hereditary degeneracy, the administrative officers in nominating persons for sterilization and in preparing cases for presentation to the courts and, finally, the courts in judging the biological evidence of hereditary degeneracy. There has been a steady growth of the biological motive in legislation, in court decisions and in the administration of these statutes. Also the compulsory feature is now soundly established in legislation and in long practice. Progress in this field demands further research in human heredity.

Racial Aspects of Crime in the United States

Ten years ago Laughlin prepared for the Congressional Committee on Immigration a statistical statement as to the proportional amount of crime in the racial stocks represented in the United States. During the past year he has made a similar study of the prisoners as of October 1, 1931. It was expected that the study would determine whether certain features of the Immigration Control Act of 1924 designed to reduce alien crime in the United States were successful. The method of race-quota fulfillment was used. Some of the findings are: Ten years ago the quota fulfillment for crime by all foreign-born was 109.91; in 1931 it was found to be 70.83, a very substantial reduction. Immigrants from Northwestern Europe reduced their quota fulfillment from 53.32 to 41.14. Italians cut their crime rate from 209.72 to 111.23. Native-born whites, only one parent foreign born, cut the rate from 113.67 to 73.75. Native-born whites, both parents foreign born, from 86.21 to 80.71. The Filipinos, not measured in 1921, gave a crime quota of 230.43. All colored races show very high crime rates. The reduction of the felony rate during ten years to one-third seems to be due to the restrictive measures of the Congressional Acts of 1921 and 1924, to the overseas examinations and to increased deportation. Laughlin draws the conclusion that, under modern conditions, immigration control is that feature of legislation that leads to greatest results in the field of applied eugenics.

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PERSONS ENGAGED IN VARIOUS ACTIVITIES DURING THE YEAR ENDING OCTOBER 31, 1932

Amos G. Avery, Associate
Annette Bacon, Assistant
Howard J. Banker, Investigator
Editii Banta, Assistant
James Barrett, Laborer
Robert W. Bates, Investigator
A. Dorothy Bergner, Cytologist
Mary Boccia, Assistant
A. F. Blakeslee, Assistant Director
J. E. Bucuris, Engineer
Marie Bucuris (Mrs.), Janitress
Edw. Burns, Farmer
Ethel E. Burtch (Mrs.), Switchboard Operator and Typist
Catherine Carley, Computer
Geo. E. Cauthen, Assistant
G. H. Claflin, Chief Clerk
Chas. B. Davenport, Director
M. Demerec, Investigator
William Drager, Assistant
Simon W. Dykshorn, Assistant
Mabel L. Earle, Editor and Library Abstractor
William Fagan, Animal Caretaker
Margaret Findley, Assistant
Lillian B. Frink, Assistant
Julia Irene Goodrich, Secretary
J. E. Griffin (Mrs.), Assistant
Edith Harrigan, Assistant
Alice Hellmer, Assistant
Paul Holm, Caretaker
Mary J. Holmes, Clerk
Ethyl I. Hunt (Mrs.), Stenographer
J. N. Johnson, Carpenter
Margaret Kaylor, Assistant
Alice Gould Laanes (Mrs.), Curator of Archives
Theophil Laanes, Assistant
Harry H. Laughlin, Assistant Director
G. A. Lebedeff, Assistant
George Macarthur, Supt. Buildings and Grounds
E. C. MacDowell, Investigator
Margaret Martin, Indexer
Elizabeth deG. McKee, Histologist and Artist
Merritt J. Murray, Assistant
Ruth Millar, Assistant
Miriam E. North, Librarian
Leslie E. Peckham, Clerk
Phyllis V. Plyler, Assistant
James S. Potter, Associate
Ronald D. Reid, Stenographer
Oscar Riddle, Investigator
Sophia Satina, Assistant
Jennie O. Schultz, Assistant
Domenico Sepe, Garden Hand
Harriet L. Smart (Mrs.), Assistant
Harold H. Smith, Assistant
Guinevere C. Smith (Mrs.), Assistant
Morris Steggerda, Investigator
Martha J. Taylor, Assistant
Clifford Valentine, Laborer
Eunice White, Assistant
Harry White, Painter

TEMPORARY, SUMMER 1932

A. M. Banta, Investigator
Leland A. Brown, Investigator
J. T. Buchholz, Investigator
J. Lincoln Cartledge, Investigator
Edith Coulter, Assistant
Caroline Denton, Assistant
Helen Houghtaling, Assistant
Lois Platt, Assistant
Mable L. Walter, Assistant
Thelma Wood, Associate
N. Timoféeff-Ressovsky, Investigator
Tage Kemp, Investigator