There is weighty argument in using the Miller symbols even with beginners in crystallography. In elementary work only type symbols are used and for these the Miller system is as easy as any. One only has to replace one index of the symbol *hkl* by a zero when a face is parallel to an axis. When it comes to a question of actual symbols the Miller indices of course take precedence over the Weiss. If one learns Miller from the start there is never the necessity of translating back and forth from Weiss, which is a waste of energy. And lastly the Miller is the only universal system.

The fact that the axial ratios are irrational and that the indices are rational is a thing that always gives many students trouble. Thus most students can not see why the symbol 111 does not represent a face that cuts the three axes *a, b* and *c* at equal lengths. The writer has used a homely illustration that usually makes it clearer at least. Take two cities, laid out in different ways. A pedestrian on inquiring about a certain building in either place might be told: Go two blocks north, three blocks east. Yet the actual distance he had to walk in the two cities would be different, for the lengths of the blocks are different. These distances are on record and correspond to the axial ratios. Yet the pedestrian is not concerned directly with them. The two blocks and three blocks correspond to the indices.

In order to really understand some of the essential points of crystallography the student must devote some time to crystal measurement, calculation and drawing. And without something of the sort, the time given to crystallography may almost be a waste of time unless it is taken up at some future time. To accomplish this in the limited time available in a general course in mineralogy is difficult. The writer has had partial success with the following method. Selected crystals or wooden models preferably orthorhombic with 110, *hk*0, 011 and one or more of 100, 010 or 001 are chosen.

(1) Free-hand sketch of the crystal.

(2) Number faces and indicate zones.

(3) Measurement of interfacial angles with the contact goniometer.

(4) Stereographic projection on sheets devised by Penfield.

(5) Graphic determination of *a* and *c* from 110 and 011.

(6) Graphic determination of indices *hk*0.

(7) Orthographic projection (plan and elevation) from stereographic.

Taken up in this manner the work is not at all difficult for the drawing of zone circles is not necessary in the stereographic projection and the tedious clinographic projection is replaced by the orthographic. Yet the student appreciates something of the meaning of axial ratios and indices and is ready, if need be, to take up more advanced work.

AUSTIN F. ROGERS.
STANFORD UNIVERSITY, CAL.

SPECIAL ARTICLES.

IS THERE DETERMINATE VARIATION?

HOWEVER willingly we incorporate in our general conception and knowledge of variation the special conception of mutations (in the de Vriesian sense) and however implicitly we accept de Vries's primrose species by mutation, we must none the less hold clearly in mind that the kind of variation still most familiar to us all is that kind variously called individual, fluctuating, continuous or Darwinian variation, and we must not for a moment, because some species may have been shown to have arisen in some other way, deem ourselves absolved from the responsibility of further testing the Darwinian assumption of species-forming by the natural selection of individuals possessing advantageous slight variations.

If new species arise by virtue of a cumulation or progressive increase of small fluctuating variations in continuous series, they can apparently only do so through (*a*) natural selection, or (*b*) determinate or orthogenetic variation. The principal argument for a belief in determinate variation so far advanced seems to be that natural selection is unable to make use of fluctuating variation because (1) this variation is too small and useless to be a handle for life and death selectivity, and because (2) of the swamping or extinguishing of favorable variations by their intermating with unfavorable or neutral conditions.

Thus there is necessary some influence tending to cumulate variation independent of, or antecedent to, selection. This influence or causal factor in species-forming on a basis of continuous variation must, therefore, be something whose result is determinate or orthogenetic variation. What can produce such progressive variation doesn't for the moment seem very obvious. But a prior consideration for observation and experiment (pedigreed breeding) may well be that of the determination of whether we can actually distinguish the occurrence of the determinate variation. If we can't discover its existence we need not trouble our fevered wits with questions of how it might be produced.

I wish, therefore, to present some facts[1] concerning a little green and black beetle that infests our Californian flower gardens—one *Diabrotica soror* or 'California flower beetle' by name—that seem to me to have intimate relation to the problem just stated.

This beetle has its black and green colors arranged on its back (dorsal surfaces of the wing-covers) in the form of twelve distinct black blotches or spots on a green ground, six spots in three transverse pairs (or two longitudinal rows) on each wing-cover. At least the original description of this species gives this patterning, and systematic accounts and revisions of the genus have always ascribed to the species *soror* twelve separate black blotches on a green (or yellow-green) ground. In Horn's revision of the genus in 1893 (*Trans. Amer. Ent. Soc.*, V. 20, p. 89 ff.) the fact of a tendency of the black spots to coalesce is fleetingly referred to. But undoubtedly the twelve-free-spots type is the pattern which is accepted as the typical and usual one.

In its larval stage this beetle lives as a slender white grub underground, feeding on the roots of alfalfa, chrysanthemum and various other plants. It pupates in a small subterranean cell near the surface and the adult beetle, on issuance from the pupal cuticle, makes its way aboveground and feeds on the buds and opened flowers of roses, chrysanthemums and almost any other of California's favorite blossoms. The color pattern of the adult is, of course (as the insect is one of 'complete metamorphosis') definitive and fixed as to both pattern and color at the time of the first appearance of the adult aboveground.

By the aid of several industrious assistants I have been able to collect from the same locality in the same months each year a thousand or more specimens of *Diabrotica soror* in each of five separate years included in the last decade. In addition, we have made other collections from other localities in California of series varying from a few score to a thousand individuals. With the help of these same indefatigable[2] helpers all of these thousands of beetles have been closely scrutinized and honestly described with regard to the actual condition of their elytral pattern. The results of this work are graphically represented in the accompanying 'frequency polygons' and statistical tabulations.

From this scrutiny and compilation it is apparent, (1) that in this patterning variations of the strictly fluctuating or continuous sort exist, as was to be expected; (2) that this variation is strongly marked and hence readily tabulatable, which is fortunate for our study; (3) that this variation does not follow Quetelet's law of error, in which characteristic it departs from the usual condition of fluctuating variation, but is not unique; (4) that this variation plainly sets strongly in a certain specific direction, that is, tends strongly toward the production of one particular new type of pattern rather than toward dissipating itself by futile equal attempts in various and thus mutually extinguishing directions; and (5) that this tendency is on the steady increase in our own times, under our very eyes.

The pattern variation is shown (by selecting certain principal types appreciably distinct)

[1] See Kellogg and Bell, 'Studies of Variation in Insects,' *Proc. Wash. Acad. Sci.*, Vol. 6, pp. 203–332, 1904, for a detailed account of the variation in *Diabrotica soror*.

[2] Instructor R. G. Bell and students R. Patterson and B. E. Wiltz.

in Fig. 1, where *A* represents the condition accepted by the systematists as typical of the species (both right and left elytra are shown); *B* shows the two spots of the middle transverse pair of the left wing-cover fused; *C*, the corresponding two spots of the right wing-cover fused; *D*, the two spots of the posterior transverse pair of the left wing-cover fused; *E*, the corresponding spots of the right wing-cover fused; *F*, the longitudinal fusing of the spots on the left wing-cover, and *G*, the corresponding condition for the right wing cover.

These different patterns are closely connected by intergrading conditions; that is, there may be (theoretically) and are (actually) all degrees of fusion of the two spots in

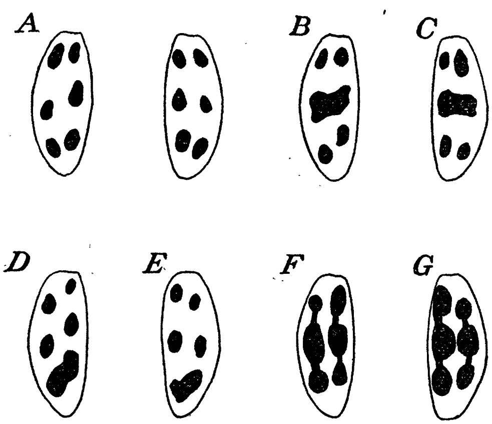

FIG. 1. Diagrammatic representation of the varying elytral color pattern of the California flower beetle, *Diabrotica soror*.

these various pairs that show fusion at all, from the slightest running together to the complete type shown by the diagrams of Fig. 1. But for the sake of aggregating individuals into describable groups any fusion is called fusion, and the existence of even the slightest space or line of green between two spots is recognized as 'no fusion' or 'free spots.' As a matter of fact, in the great majority (about five sixths) of cases of fusion the spots are well joined.

In the following tabulations and graphic representations (by frequency polygons) of the condition of the varying color pattern in the species (on the Stanford University campus) in different years, series of approximately 1,000 are used. That a series of 1,000 individuals collected from one locality at one time fairly represents, in the variation revealed by its members, the actual variation conditions of the species in this locality, as regards both kinds of variation and frequency of these kinds, is proved by repeated tests made by examining and tabulating successive

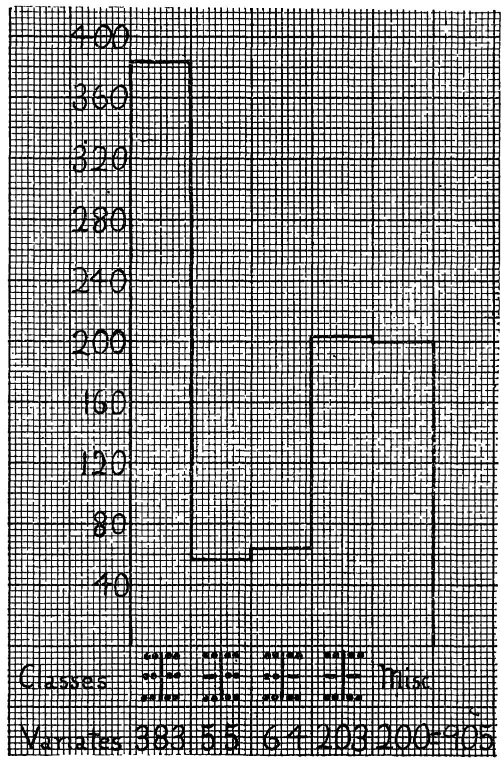

FIG. 2. Frequency polygon of the variation in elytral pattern of 905 specimens of the California flower beetle, *Diabrotica soror*, collected on the Stanford University campus, 1895.

thousands and finding a practical identity in these separate series. Indeed, series of 500 gave practically always approximately the same curve as those of 1,000. But the larger number is the safer.

Attending now to the actual variability shown by the elytral color-pattern of *Diabrotica soror* in the various series examined (in the years 1895, 1901, 1902, 1904 and 1905), we find the species in 1895 showing (Fig. 2

and caption) a marked preponderance of the twelve-spots-free condition (*A* in Fig. 1) over any other pattern type, but a much stronger proportion of a certain one of the variant types than of any other form of variant. This second modal type is the one in which the members of the middle pairs of spots are fused on both wing-covers (*B* and *C* of Fig. 1). The other important variants are middle spots fused on either right *or* left wing-cover, posterior spots fused on either or both right and left wing-covers, and various longitudinal fusings. Fig. 2 and its caption give the exact data of the arrangement of this variability. (The transverse fusing of the posterior spots and all the longitudinal fusings are grouped together as 'misc.')

But note now Figs. 3, 4, 5, 6 and 7, with their captions, giving the condition of this color-pattern variation in the years 1901, 1902, 1904 and 1905, respectively. In all these cases the variant $B + C$ or middle-spots-fused type is the predominating form. The following table shows the relative frequencies of the modal-pattern types in these successive years.

	All Spots Free.	Middle Spots Fused.
1895	42.35	22.40
1901	34.05	43.70
1902	34.05	42.80
1904	20.90	65.40
1905	35.20	46.50
1905[3]	26.87	53.92

If series of 1,000 really reveal the variation conditions of the color pattern in the species in these different years (and our check lots show that they do) it is apparent from these statistics that *Diabrotica soror,* in this particular locality has, in ten years, changed from a form in which one pattern type was the mode to one in which another is the mode. And this change has been gradual and cumulative; not made by a mutation or by discontinuous variation, *i. e.,* discontinuous evolution. The two modes or predominant types of pattern are connected to-day as they were ten years ago by all degrees of gradations; the variation, that is, is typically continuous or 'Darwinian' in type. Excluding then the mutation or discontinuous variation explanation of this species change there remain three possible explanations of the change (on the basis of current theories of species-modification); these are: (1) the change is simply ontogenetic, determined for each generation during its development by extrinsic influences; (2) the change is the result of natural selection; and (3) the change is due to determinate variation.

[3] The second 1905 series was collected at a distance of several miles from the locality on the campus from which the other lots were taken.

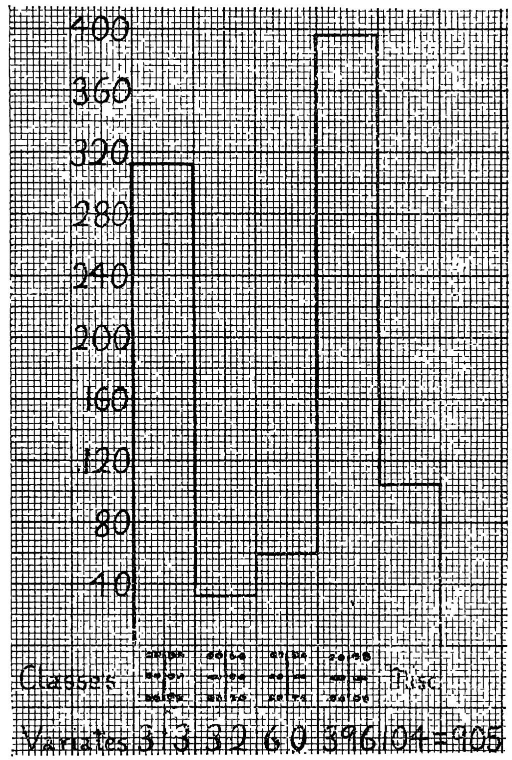

Fig. 3. Frequency polygon of the variation in elytral pattern of 905 specimens of the California flower beetle, *Diabrotica soror,* collected on the Stanford University campus, October, 1901.

The first explanation involves the assumption that the pattern is not inherited as such, but is acquired during the ontogeny of each individual as a result of environmental influence; and it further has to assume a present total environmental influence in this particular locality different from that in 1895 in the degree and to the effect that it tends to cause an irregular transverse blotch (plainly formed by the fusion of two original separate blotches or spots) to appear in place of a transversal pair of blotches. As to the first assumption, the fact that the forming of the color pattern of the beetle requires but an hour or so, that it is carried on underground in the pupal cell, and that it is at no time exposed to above-

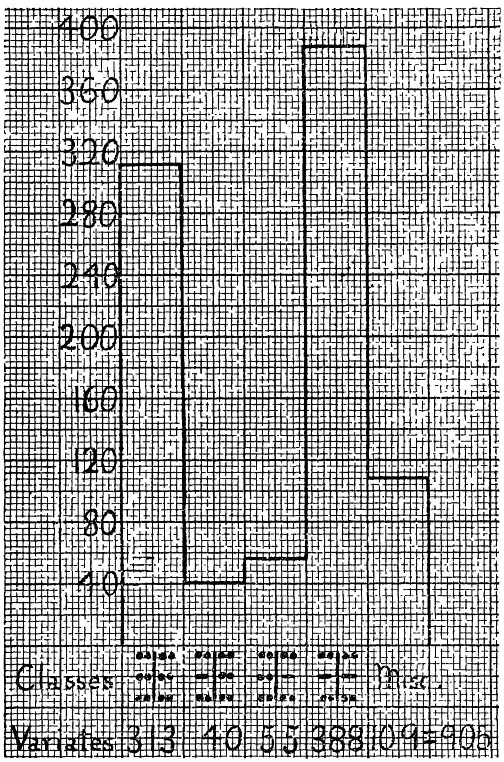

FIG. 4. Frequency polygon of the variation in elytral pattern of 905 specimens of the California flower beetle, *Diabrotica soror*, collected on the Stanford University campus, October, 1902.

ground conditions until it is in definitive unchangeable condition, and further that experiments with related species of Chrysomelid beetles (unfortunately not with this particular one) in the way of submitting the pupa and just-issued pattern-forming adult to various different conditions of light, temperature, humidity and color-surroundings, failed to produce any positive results whatever; all these facts strongly tend to invalidate the assumption of an ontogenetic determination of the color pattern. The second assumption, that of a change in environment in ten years sufficient to produce consistent ontogenetic

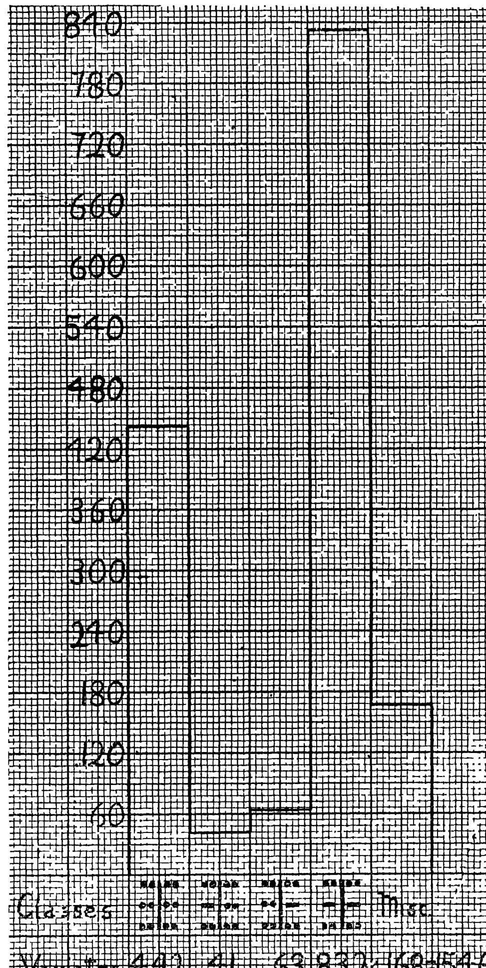

FIG. 5. Frequency polygon of the variation in elytral pattern of 1,546 specimens of the California flower beetle, *Diabrotica soror*, collected on the Stanford University campus, October, 1904.

changes in the color-pattern, certainly does violence to our knowledge, as far as it goes, of meteorological, cultural and other life-influencing conditions on our campus. No such changes are apparent.

The second explanation, that of natural

selection, based on a rigid intra-specific or individual selecting, tending to preserve the middle-spots-fused condition at the expense of the middle-spots-free condition, assumes an actual visual discrimination—let alone a presumable esthetic or preferential one—on the part of the lizards, birds and insect enemies of *Diabrotica;* that is, to be flippant, coming it much too strong for me. We really know

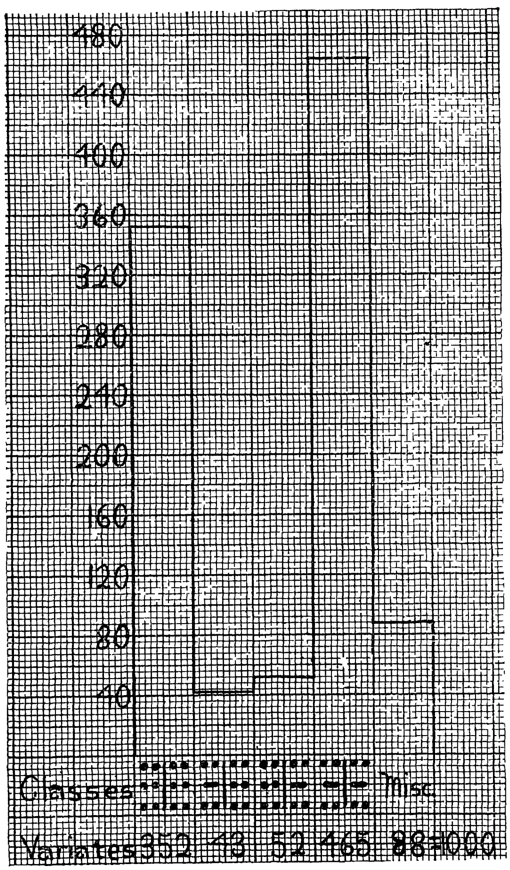

Fig. 6. Frequency polygon of the variation in elytral pattern of 1,000 specimens of the California flower beetle, *Diabrotica soror*, collected on the Stanford University campus, October, 1905.

something about the eyesight of lizards, birds and insects and it is fantastic to credit them with a capacity for distinguishing a character that in many cases requires on our part careful scrutiny with a lens to make out. When we straighten up after an hour's eye-straining work on this minute, though none the less real and from the species-student's point of view important, variation condition among our hosts of beetle specimens, we have in our minds one conviction about which there is moral certainty, and that is that no lizard,

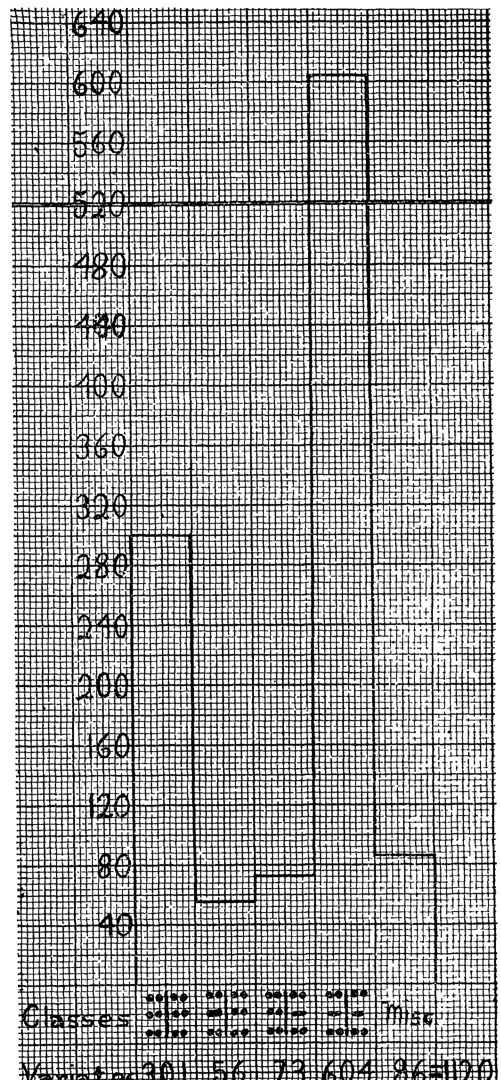

Fig. 7. Frequency polygon of the variation in elytral pattern of 1,120 specimens of the California flower beetle, *Diabrotica soror*, collected in the foothills of the Sierra Morena Mountains, about three miles from the Stanford University campus, October, 1905.

bird or insect is going to distinguish between beetle *A* and beetle *B* by the middle-spots-free or middle-spots-fused criterion. For one, I am done with meekly accepting the dictum of the selection champions who declare, in such cases as the present one, that we do not know what difference in general effect of harmony with leaf or flower or what not, and hence with the safety of the beetle, a very slight modification of pattern may produce; that we can not say of any difference, however minute, or apparently indifferent, that it is not the hair in the balance; and that when we understand *all* the conditions of the life of an or-

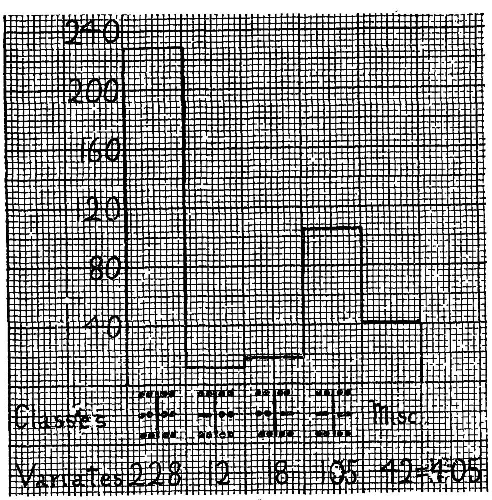

FIG. 8. Frequency polygon of the variation in elytral pattern of 405 specimens of the California flower beetle, *Diabrotica soror*, collected at Santa Rosa, California, about sixty miles north of the Stanford University campus, October, 1902.

ganism, then, and only then, are we entitled to say of this or that character that it is not of life-and-death value. When we accept such a dictum we put aside all need of study, all spur to work, for '*all* the conditions' is a phrase to crush with. However, there are but few selectionists left who insist any longer on taking this point of view. Practically all Neo-Darwinians admit the existence of hosts of trifling, insignificant, indifferent species and variety characters. As for those who still hold to their crushing dictum—well, we can simply refuse to crush.

In the particular instance before us, harmony of the color pattern of our beetle with its environment is out of the question. In fact, the glaring disharmony of the chrysomelid beetles with their habitual green leaf environment has been long notorious and has offered them a general card of admission to the group, probably not wholly fanciful, of 'aposematically' patterned animals, that is, creatures of malodor or distaste to their vertebrate enemies and conspicuously colored to warn these enemies of the malease which gastronomic attention to them will produce. So that the selective value of two-spots-fused or two-spots-free is that of helping make the pattern a distinct and readily perceived one. Now throughout the whole great family of Chrysomelid beetles the prevailing patterns are stripes, longitudinal or transverse, spots, and a clear ground color with neither spots nor stripes. In genus after genus in this family these three types of patterning are all represented by species of apparently equal abundance, vigor and general success in making life a burden to the horticulturalist and farmer. And these species with their different pattern types may, and often do, live side by side. Precisely in the genus *Diabrotica* is this interesting condition of things excellently exemplified. In the Mississippi Valley *Diabrotica longicornis*, with its unpatterned blue back, eats the sweet corn of the truck farmer, while the longitudinally black-striped *D. vittata* eats his cucumbers and melons, and the yellow *D. 12-punctata*, with its twelve separate black spots, attends to the rest of the truck. Here in California we are able to distinguish *D. soror* from *12-punctata* which ranges up to us from the middle west and great southwest only by the fact, quite sufficient for systematic coleopterologists, that the *under side* of thorax and abdomen and the bases of the legs (all parts well out of sight of preying lizard or bird) are strongly dusky instead of yellow. The exposed dorsal color pattern is the same in both. So that the differentiation of these two species was certainly never brought about by any selection of protective warning color-pattern variations.

We have also in our range a striped form, *trivittata,* hardly distinguishable from vittata.

Thus unstriped and unspotted or striped or spotted, all seem good patterns in the eyes of selection. To me, it is as clear as the significance of any fact in nature is clear, that the change in our locality in *Diabrotica soror* from a beetle species of typical twelve-spots-free pattern to one of eight-spots-free and two irregular transverse blotches in place of the middle four spots is not due to natural selection.

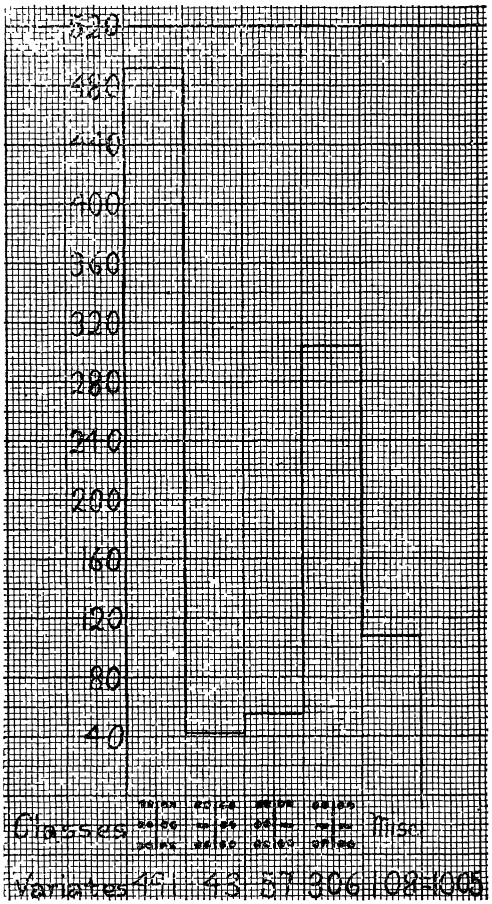

FIG. 9. Frequency polygon of the variation in elytral pattern of 1,005 specimens of the California flower beetle, *Diabrotica soror,* collected at San Jose, California, twenty miles south of the Stanford University campus, October and November, 1905.

As to the third explanation, that of determinate variation, I have to say, simply, that there remains of our possible three explanations, one, which is that of determinate variation. But, we must note, if determinate variation is the explanation of this change in *Diabrotica soror* it is a determinate variation which is occurring only, apparently, in our particular locality. For in series of specimens of this bettle collected in other parts of California no such change seems to be going on, the old twelve-spots-free form being plainly the modal type. For example, in a series of 405 specimens collected in Santa Rosa, which is about sixty miles north of Stanford University, there are twice as many individuals with all spots free as of those with middle spots fused. (See Fig. 8 and caption.) And in a series of 1,005 individuals collected at San Jose, which is twenty miles south of Stanford University, nearly 49 per cent. are of the twelve-spots-free type and only 30.5 per cent. of the middle-spots-fused type.

Why the species should be changing on our university campus and not changing in the regions south and north of us is a mystery whose solution I do not even dare to guess at. This solution must have to do with the cause of the variation of the species on our campus. But if one asks what is this cause, what it is that is producing determinate variation in *Diabrotica,* or in any other species, I have, in this connection, only to refer to a statement in the beginning of this note, which is to the effect that prior to any attempt to explain how determinate variation might be produced it is advisable to attempt to determine if determinate variation really exists. Is there determinate variation?

VERNON L. KELLOGG.
STANFORD UNIVERSITY.

DISCOVERY OF AN EARLY TYPE OF MAN IN NEBRASKA.

IN a circular mound recently opened on a Loess hill north of Florence, near Omaha, Nebraska, various skeletal parts, and eight human skulls of a primitive type were exposed. The credit of the discovery belongs