per cent, related, and the part of the inbreeding due to relationship between his sire and dam is 59.82 per cent. of the actual total inbreeding.

In Fig. 1 the inbreeding curve and the relationship curve are plotted, based on the figures given in Table I, the former as a solid line, the latter as a broken line. The smooth curve indicates the maximum inbreeding curve; the broken line, that divides the area in two equal halves, indicates the maximum relationship curve. These four curves taken together give a fairly good graphical demonstration of the facts in question.

1. The area OABX in relation to the area OAEX gives the proportion of the actual to the maximum degree of inbreeding: *The total inbreeding coefficient.*

2. The area OACX in relation to the area ODFX indicates the proportion of the actual to the maximum degree of relationship: *The total relationship coefficient.*

3. The area OACX in relation to the area OABX gives the proportion of the inbreeding that is due to relationship: *The total relationship inbreeding index.*

In bringing all measurements of degrees of inbreeding and relationship to the same scale and using areas as the measures we get a uniform and significant series of coefficients that numerically express the degree of inbreeding and relationship in a given pedigree.

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SOME OBSERVATIONS CONCERNING THE PERIODICAL CICADA

DURING the recent visitation of the periodical cicada, their great abundance on the writer's home grounds at Vinson Station, Va., afforded an excellent opportunity to observe some of the habits of these interesting insects. During the months of January, February and March, the writer was engaged in clearing off all trees and brush from several lots immediately adjoining his home grounds. In the course of this work, several large oak trees were completely dug up by the roots. Even during the winter months, many of these benumbed creatures were encountered in their burrows in the soil around the roots. As warmer weather approached, their burrows became more numerous in the soil and it was evident that they were approaching the warmer, uppermost layer in ever-increasing numbers. Finally,

on May 18, the first adult was seen making its weak flight over my garden, having emerged some time during the previous night. A few evenings later the great exodus had begun in earnest and thousands of pupæ were issuing from the ground after sundown and ascending all the bushes, trees and posts in the vicinity to transform.

Although the actual exodus from the ground does not take place until after sundown each evening, the pupæ, in preparation for the event, excavate their burrows to the very surface of the ground and await the setting of the sun. In some instances the creatures burrow just to the surface, leaving a very thin layer of soil undisturbed over the exit. Frequently a tiny hole is punctured in the center of this thin surface layer. If these burrows are cautiously approached late in the afternoon long before sundown, the heads of the creatures may be seen near the surface. As the light intensity wanes with the oncoming of evening, the creatures come to the very surface, but quickly retreat if approached or disturbed. It is evident that the pupæ are negatively phototropic. If a pail or box is inverted over their burrows long before sundown so as to exclude the light, the creatures will shortly emerge as if night were really at hand. In this way I have brought many pupæ out of their burrows in broad daylight.

Although the pupæ quickly transform after emerging from the ground, it would be of interest to know just what conditions, external or internal, determine the impulse to prepare for the adult stage. If the creatures are prevented from leaving the ground or soil, the following experiments indicate that the pupæ will remain as such at least a day or two longer than when allowed to ascend trees and shrubs in the normal manner.

On the evening of May 24, five pupæ just emerging from the ground were captured and placed on the damp bare ground beneath a large inverted flowerpot, the drainage hole at the bottom of which had been closed. In addition to these, six other pupæ were captured and placed in a large flowerpot of similar size filled even to the top with loose soil. This pot was covered with a board. Both pots were examined next morning. The pupæ placed on the bare ground beneath the inverted, empty flowerpot were still crawling around, and none had transformed. Of the six placed in the pot containing soil, one had died. The remaining five were alive and active, and likewise none of these had transformed.

On May 25, the following experiment was made with these creatures. Early in the evening before the time had arrived when the creatures usually emerge in response to the low light intensity prevailing after sundown, many were captured by inverting boxes, etc., over the burrows. Later in the evening many more pupæ were captured as they were emerging from the ground in response to the normal darkness following sundown. Six were again placed on the damp earth beneath an empty, inverted flowerpot. Nine were placed as before in a full pot of soil, over which a board was placed to prevent their escape. As controls, six were placed on the branches of a shrub and kept under observation. One of the controls fell off and escaped. The remaining five soon transformed in the normal manner. The next morning, May 26, the pupæ kept beneath the empty, inverted pot and those in the soil were examined. Of the six placed on the bare soil beneath the empty, inverted pot, one had died but the rest were active. None had transformed. All nine pupæ placed in the pot containing soil were alive and crawling over the top of the soil. Likewise none of these had transformed. On the evening of May 26, three of these had died, but the remaining six were as lively as ever. These were then given their freedom and were allowed to crawl up into the branches of a small fringe tree nearby. One fell off and was lost, but the remaining five completed their transformations in the normal manner. Whether this temporary inhibition of the act of transformation is volitional or depends upon some factor of the soil environment acting upon them is not definitely established by these experiments.

After the pupæ ascend the shrubs and trees, rigidity sooner or later takes place, and the adult begins its emergence from the dorsal slit which opens in the pupal skin. It is not long until the lax, soft-bodied creature is hanging head downward by the tip of the abdomen. At this stage of its emergence, when it appears as if the helpless, soft-bodied creature must fall to the ground and perhaps suffer injury, it becomes very active, actually bending up to catch the exuvium or other near object with its legs, just before the tip of the abdomen is released. Not all pupæ are fortunate in their travels and transformations, however, for many come tumbling to the ground from the trees while they are making their way up the trunk and limbs. The almost helpless transformed adults also sometimes fail to secure a foothold and fall to the ground. It is interesting to note how quickly pigmen-

tation is completed after transformation. Immediately after emerging from the pupal shells, the adults are pale yellowish white, with two large conspicuous jet-black areas on the yellowish white prothorax. In a few hours the entire prothorax develops this same black pigment and becomes almost uniformly black.

In some localities the pupæ, in response to special conditions, construct neat little chimneys of earth several inches in height into which their burrows lead. I did not, however, find a single specimen of these unique structures in my locality, although the soil conditions varied greatly.

At Vinson Station, I was afforded an excellent opportunity to observe the occurrence, habits and notes of the dwarf or casinii form as well as the typical, much larger form, since both occurred here. Although the earliest musical expressions of the larger form were heard at my home on May 24, the distinctive notes of the dwarf form were not heard until nearly a week later. A rather well-defined colony of these smaller cicades appeared in some low, shrubby oaks only a few rods from my home, and remained locally abundant here throughout the period of their visitation. It was here that I spent much time in observing their habits. Although the pupæ of the larger and the dwarf form emerged from the ground within the same area in some places, and both forms were singing in the same trees and shrubs, both species appeared to mate among themselves. At no time did I observe a single instance of cross-mating. Although now and then I heard an occasional casinii form singing in the nearby woods, this form confined itself almost entirely to the narrow limits of the shrubby oak growths where it first appeared.

It now remains to consider the "songs" or musical notes of the larger and the smaller forms, for they are entirely different in character. The song of the larger form is a low, and to my ear usually pleasing, droning,—ah-oo—ah-oo—ah-oo—ah-oo—ah-oo. The first, or "ah" syllable is higher in tone and slurs down to the much lower pitch expressed by the syllable "oo." Each phrase "ah-oo" requires about five seconds, and the entire series may be prolonged for many seconds. During the act of "singing," the abdomen is noticeably raised toward the wings on every "ah" syllable, and is lowered on the lower-pitched "oo" syllable.

The "song" of the small Casinii form is a dry, lisping, tone-

less series of sounds, which to me seem best described by the syllables "it-see—it-see—it-see—it-see—it-see—it-see—see—see—see—see." The entire series of notes is hurriedly delivered and does not usually last over 8 to 10 seconds. The first notes of the series—"it-see—it-see "—usually begin slowly and are somewhat subdued in character. The syllables "it-see" gradually increase in loudness, and finally decrease somewhat in intensity, as they run into the shorter, more subduel syllables "see—see—see—see" which terminate the complete "song." The notes of this form are soft and lisping in character, and remind one of the noise of steam escaping intermittently, as one sometimes hears it around a locomotive.

During the height of the "song" season, one could rarely distinguish the notes of any individual, for the myriads of "voices" blended into a volume of soft, murmurous sound—a veritable atmosphere of sound which seemed everywhere to invest the trees and landscape from daybreak till darkness. It was a steady, droning, unceasing hum like the even whirr of machinery. The trees in the National Cemetery were fairly swarming with these creatures and their steady, murmurous chorus could be heard from morning until night, at a distance becoming softened and subdued, and reminding one of the soft murmurs heard when a big sea shell is held to one's ears.

Although the periodical cicada usually becomes silent after sundown, a great nocturnal chorus is sometimes initiated and a remarkable wave of sound invests the night for a time. On the night of May 31, I heard a most memorable, nocturnal chorus of this character, which began just before 2 A.M., solar time. One or two singers in the oak trees in my back yard initiated the concert. Others joined in, and there was a gradual swelling in the volume of sound until it seemed as if all the creatures in these trees were in full song. The concert did not stop here, for I heard it passing on to the big woods toward tulip poplar swamp, until the nighttime was fairly filled with murmurous sound. Gradually the crest of the wave passed outward into the more distant woods, while it subsided slowly in the trees in my back yard where the musical impulse appeared to originate. After some minutes all was quiet again around me, although I could just hear the great wave of sound receding or dying away in the distance. It was the most weird and remarkable chorus I have

ever heard. Hopkins describes a similar instance of this spectacular, nocturnal singing which he once heard.[1]

Many species of birds appeared to find these cicadas especially acceptable morsels. The blue birds in my boxes fed their young upon them extensively, as did a pair of song sparrows which had their nest in a pile of roots in my back yard. House wrens, English sparrows, red-headed woodpeckers and cuckoos fed upon them greedily. Some birds appeared frequently to snap them up in mere play as I once saw a cuckoo doing in the branches of a maple tree over my head. This bird snapped up first one then another in quick succession, quickly dropping them one by one, in a badly injured, helpless condition.

It is of interest to note that individuals differ in eye color. I have noted the following:

1. Males and females with red eye color.
2. Males and females with orange eye color.
3. Males and females with light buff eye color.
4. One male with noticeably white eye color. This individual was distinctive in other respects, since the large veins of the wings, markedly reddish in the common, red-eyed form, were pale yellowish in color. Red-eyed individuals predominate.

Some of the more important dates in the occurrences of the periodical cicada at Vinson Station I have recorded in my journal as follows:

May 18—First adult seen on the wing. The great exodus from the soil began during the next few days.

May 24—First "singing" of larger form heard. First singing of smaller Casinii form heard some days later, about May 27 to May 30.

May 30—Large form in copulation generally. First female noticed laying eggs in twigs.

June 5—Egg-laying activities at their height.

June 14—Creatures becoming very rare, and individual singers only occasionally heard.

June 20—All silent.

June 27—A single, belated individual of the larger form heard in "song."

Although the incessant concerts of the periodical cicadas persisting from morning until night became almost disquieting at

[1] See "The Periodical Cicada," by C. L. Marlatt, Bull. No. 14, Div. of Ent., U. S. Dept. of Agr., 1898, page 58.

times, I felt a positive sadness when I realized that the great visitation was over, and there was silence in the world again, and all were dead that had so recently lived and filled the world with noise and movement. It was almost a painful silence, and I could not but feel that I had lived to witness one of the great events of existence, comparable to the occurrence of a notable eclipse or the visitation of a great comet. Then again the event marked a definite period in my life, and I could not but wonder how changed would be my surroundings, my experiences, my attitude toward life, should I live to see them occur again seventeen years later.

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THE BEHAVIOR OF FUNDULUS HETEROCLITUS ON THE SALT MARSHES OF NEW JERSEY

DURING the year 1914–'15 the writer was retained as consulting zoologist to the department of entomology of the New Jersey Agricultural Experiment Station and engaged in studying the fish enemies of the salt marsh mosquitoes. At that time it became evident that *Fundulus heteroclitus* is the most important predatory fish attacking the salt marsh mosquitoes of northern waters. Much evidence of the efficiency of *Fundulus heteroclitus* as a mosquito exterminator has already been published (Chidester, 1916). Certain notes on its behavior under varied conditions have been amplified by more recent observations and are herewith presented in connection with the problem of migration in fishes.

In New Jersey the fish were studied under natural conditions for over a year on the salt marshes near the city of New Brunswick. Through the report system of the state inspectors of the Mosquito Commission, much important information was secured regarding conditions in other parts of the state. Experimental conditions were induced in the field by drainage ditches and in the laboratory by the use of aquaria. Other studies were made at Woods Hole, Mass., for several years during a portion of the month of June.

MATERIAL AND METHODS

On the salt marshes where the chief study was made there were numerous pools, some permanent, others easily differenti-