expect alterations in the current theory if a non-linear theory is correct.

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THE QUESTION OF WILDLIFE DESTRUCTION BY THE AUTOMOBILE

IN connection with the steady increase in the volume of automobile traffic in recent years considerable attention has been given to the killing of animals straying on or deliberately crossing the highways in search of food, water or other environmental requirements. In previous issues of SCIENCE observations on the extent of such destruction have been reported. Stoner,[1] 1925, observed 225 dead animals on the highway in Iowa during a three-day trip of 632 miles. Davis,[2] 1934, reported the destruction of 179 animals in two days on a stretch of 500 miles enroute from Iowa to Amherst, Massachusetts. These two observations each indicate an average of .36 dead animals per mile. This appears to be an alarming rate of destruction. Nor is the bulk of this killing confined to cats, dogs and fowls. Stoner lists 28 species, and instances of killing such large animals as a deer are known.

In the light of these facts an observation made on a 1,500-mile trip from Chicago, Illinois, to Woods Hole, Massachusetts, from June 26 to July 1, 1935, and on a return trip of 1,050 miles from Woods Hole to Cincinnati, Ohio, from September 1 to 4, 1935, appears to be particularly interesting. The following dead animals[3] were seen on or at the side of the road.

1. Cat (*Felis domestica*)	3
2. Chipmunk (*Tamias striatus*)	1
3. Dog (*Canis familiaris*)	5
4. Muskrat (*Ondatra zibethica*)	1
5. Rabbit (*Sylvilagus floridanus*)	3
6. Rat (*Rattus norvegicus*)	2
7. Skunk (*Mephitis nigra*)	8
8. Squirrel (*Sciurus carolinensis*)	1
9. Squirrel (*Sciurus niger*)	1
10. Downy woodpecker (*Dryobates pubescens medianus*)	1
11. Flicker (*Colaptes auratus luteus*)	1
12. Fowl (*Gallus domesticus*)	3
13. Robin (*Planesticus migratorius*)	3
14. Sparrow (*Passer domesticus*)	1
15. Garter snake (*Thamnophis sirtalis*)	3
16. Turtle (*Chelydra serpentina*)	2
17. Turtle (*Terrapene carolina*)	16
18. Unidentified	6
Total	61

[1] Dayton Stoner, SCIENCE, 61: 56–58.
[2] Wm. H. Davis, SCIENCE, 79: 504–505.
[3] Species according to H. S. Pratt, "Vertebrate Animals of the United States," Blakiston, 1935, and E. H. Forbush, "Birds of Massachusetts and Other New England States," Mass. Dept. Agric., 1925–29.

This total of 61 dead animals in 2,550 miles is an average destruction of .024 animals per mile, which is only one fifteenth the rate of killing reported by Stoner and Davis. On the basis that no carcass was more than 48 hours old when observed, the calculated rates of killing in the two cases, .36 and .024, indicate death rates of .18 and .012 animals per mile per day. Applying these death rates to the 750,000 miles[4] of hard-surfaced and improved roads in the United States produces an estimated killing of 135,000 animals per day, according to the Stoner and Davis figures, as compared with 9,000 per day on the basis of the present figures. Considering the great mileage of slightly traveled roads included in the total mileage and the close relation of speed and volume of traffic to rate of killing, it is believed that the lower rate of killing is too high for a daily nation-wide rate. Even at the higher rate, the killing, calculated for a corresponding period of time, amounts to only four fifths of the estimated annual (1935) slaughter of ducks alone, five to six million,[5] in a hunting season of thirty days.

From the author's point of view, *i.e.*, destruction of wildlife, the eleven cats, dogs and fowls listed are of no significance but are included for the sake of comparison with other such lists. Excluding these eleven animals from the calculations the observed death rate per mile per day for wildlife only is .0098, a rate which would produce an estimated daily destruction in the entire United States of 7,350 animals.

It is evident from the present observation that the automobile is not uniformly so great a menace to wild life as the death rate of .18 animals per mile per day, suggested by previous observations, would indicate. The Davis records of one dead rabbit per mile for 100 miles in Ohio or 200 dead animals in two miles of woodland road must be exceptional cases of destruction, at least as unusual as some may consider the present observation of only 61 dead in 2,550 miles. It is further indicated that the rate of killing may vary greatly from year to year, and also within a single season, probably in relation to marked departures from the normal temperature, humidity and precipitation, or in relation to seasonal activities of the animals. Hot dry summers, such as the seasons of 1933 and 1934, produce a definite alteration and limitation of the usual normal habitats and result in restless, exploratory activity on the part of the local fauna, bringing the animals into increased contact with the motor traffic on the highways. This movement, and accordingly the amount of killing, would be much less under the normal temperate conditions prevailing in the region surveyed

[4] U. S. Dept. of Agric., Bureau of Public Roads, Table M-5 (1930) and M-4 (1933).
[5] *Time*, August 12, 1935.

during the summer of 1935. Seasonal movements of some animals, in connection with breeding or hibernation, may result in their greater destruction temporarily, but such killing is no basis for the estimation of a continuous daily rate of killing. Finally, let no sweeping conclusions as to the destructiveness of the automobile in respect to wildlife be drawn from such limited and variable observations as have been described here. The problem is in need of a systematic statistical survey covering several seasons and various localities.

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IS A PACEMAKER INVOLVED IN SYNCHRONOUS FLASHING OF FIREFLIES?

ONE hesitates to add another discussion to the long series already published on the fascinating problem of synchronous flashing of fireflies. The existence of this phenomenon in the tropical Orient is well established, and good descriptions of it have appeared in this journal[1, 2] and elsewhere.[3] It is so easily observable in Siam that some of the efforts to explain it away are "more remarkable than the phenomenon itself."[2] However, my own observations suggest that the mechanism which maintains the synchrony involves a pacemaker, with stimulation through the light, a view not altogether in accord with previously published statements, but in agreement with a recent general interpretation of such phenomena.[4]

The phenomenon, during certain seasons,[1] may be readily observed from a boat in the Chao P'ya River between Bangkok and the sea. At some distance from the shore one may observe flashing in mangrove trees extending (at my estimate) for a quarter of a mile or more up and down the river. Although all the insects in these trees are flashing at the same frequency, and seem at first glance to be flashing in perfect unison, it has been my observation that each flash appears as a pulse of light that moves with great rapidity across the field of vision from one side to the other. In other words, in a long stretch of shore one may detect a slight *difference in time* of flashing (though *not in frequency*) between the insects that are some distance apart. My wife and others with me have verified this observation. Perhaps it could not be made satisfactorily in a small area, because, in spite of the high frequency (over ninety flashes per minute), all the trees visible at one time are darkened between consecutive flashes. In other words, if, as seems likely from this observation, a pacemaker stimulates the synchrony, the latent period of response to the stimulus by the individual insects is extremely short.

Morrison[1] pointed out two facts that are in accord with this interpretation, (1) the synchronism of the flashing may be inhibited by "exposing them [the fireflies] to a bright light for about a minute," and (2) "when the light is turned off, the synchronism returns, having its origin, apparently, in some individual or group generally located in the central part of the tree. From this group, then, the synchronism extends over the entire tree in an irregular wave until all of the insects are flashing in unison." However, he did not believe that the synchrony once established involved a pacemaker: "Furthermore, any follow-the-leader action on the part of the insects would result in a wave of light passing over the tree and originating from a definite point, a fact which is not the case once the synchronism has begun." What I have observed is this particular bit of crucial evidence—not a wave of light passing over a single tree, however, but a wave of light passing over a long row of trees.

Of some interest in connection with the suggestion of a permanent pacemaker are the experiments described by Hess.[5] In one of the rare observations of synchronous flashing of American species, in this case in a valley near Ithaca, New York, he found that he could initiate synchronous flashing by means of a pocket flashlight and even cause the insects to adopt a somewhat higher frequency.

It is not difficult to conceive of an internal mechanism which would make possible such a rhythmic behavior in a single individual. It might be some kind of recovery mechanism, as was early suggested.[6] A greater problem lies in the explanation of a synchrony which involves so many thousands of individuals; although, of course, a recovery mechanism may very well have a part in determining the frequency. A mechanism which is responsible for rhythmic behavior does not explain the synchronism of rhythmic behavior in different individuals. That seems to require an integrative factor. My own suggestion is that a pacemaker is a continuous as well as an initiating factor. In the absence of a pacemaker mechanism we should be forced to postulate the existence of an accurate physiological chronometer, a mechanism to most of us quite inconceivable.

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THE FIRST SCHOOL OF CHEMISTRY

I HAVE just been reading Thomas T. Read's short article[1] on the First School of Chemistry, in which he

1 T. F. Morrison, SCIENCE, 69: 400–401, 1929.
2 Hugh M. Smith, SCIENCE, 82: 151–152, 1935.
3 T. F. Morrison, *Journal of the Siam Society, Natural History Supplement*, 7: 71–81, 1927.
4 W. C. Allee, "Animal Aggregations," pp. 88–96. Chicago, 1931.
5 W. N. Hess, *Biological Bulletin*, 38: 39–77, 1920.
6 K. G. Blair, *Nature*, 96:411–415, 1915.
1 SCIENCE, October 18, 1935, page 371.