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UPSETTING THE BALANCE OF NATURE, WITH SPECIAL REFERENCE TO KANSAS AND THE GREAT PLAINS[1]

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A HUNDRED years ago, the great plains were still largely in their primeval state. A balance of biological life or of organic groups had been set up through the ages and this balance probably then was but little disturbed. The land at that time was in permanent sod. This sod, in Kansas, was made up largely of some 40 species of grasses out of the known 372 species of the state. The plains probably were burned off every few years by fires, started by the Indians or by lightning. In the valleys and gullies, a few scrubby oaks and cottonwoods, honey locusts and elms had escaped the fires and were maintaining a rather difficult existence. Herds of bison roamed the prairies, but they disturbed the vegetation little, since they did not stay long in any one place. Rattlesnakes, bullsnakes, coyotes, wolves, hawks and owls preyed largely upon the rabbits, ground birds, pocket gophers and prairie dogs. Great flocks of carrier pigeons roosted in the trees and, together with prairie-chickens, sage hens and bob-whites, fed upon berries, the seed of many weeds and grasses and many kinds of insects. Swarms of grasshoppers came occasionally, and no doubt at least partly defoliated the grasslands and the trees, but they were dealing with perennial plants then and these withstood the onslaughts of the hoppers.

About one hundred years ago the scene began to change, slowly at first but profoundly, nevertheless.

[1] Contribution No. 399 from the Department of Entomology, University of Kansas.

[2] Presidential address, delivered before the Kansas Academy of Science, McPherson, Kansas, on April 5, 1932.

Man, that great disturber of natural balances, came to this area, sometimes called the "Great American Desert," to establish homes and to wrest a living out of this virgin soil. He killed, often for pleasure, the bison, prairie chickens, sage hens, carrier pigeons and most of the snakes. He brought with him cattle to fatten and multiply on these fertile plains. He brought tools which tore up the aged sod, after which he planted some other grasses, such as corn, wheat, oats, rye, barley and sorghums. These plants were annuals, however, and far more delicate than nature's crop. This process which has continued to the present, has caused the great plains to lose more and more their old identity. Areas of virgin sod are not extensive now, except on the hill tops, which are good for little, agriculturally, but permanent pasture. Intensive grazing, even of these areas, has largely changed them from their primitive conditions. Prairie fires are no longer a factor, and Kansas to-day is one of the few states in the Union which has more trees than when it was settled.

Within the memory of the older residents, badgers were plentiful in Kansas. These animals are almost wholly insectivorous and helped to check the ancient pests of the still more ancient sod. Badgers are now very scarce in this state. The beaver likewise was fairly plentiful in the state, but they became a rarity before horseless vehicles appeared on the highways.

These profound changes have been accompanied by a recognizable series of biological phenomena which might be expected to follow, upsetting this ancient harmony among living things. It is my purpose to point out, not only some of the evidences, chiefly among our insect problems, of this unbalanced condition in nature, but also to offer some explanations for present wide fluctuations and to point out some of the forces working towards the establishment of a new balance.

The phrase, "balance of nature," is used to define that relative constancy of numbers of plants and animals over a long period of years, such that fluctuations in numbers ordinarily occur within relatively narrow limits only.[3]

One can not discuss animal populations without considering plant associations also, for the whole is a biological complex of the most intricate associations, as many writers have pointed out. The plant ecologists refer to this balance or complex among plants as "climax formation."[4] I shall, however, discuss animals primarily and refer to plants only somewhat incidentally.

The annual population in nature of any short-lived plant or animal can be represented, not by a straight line, but by a narrowly undulating line about a straight line expressing a general average. Outbreaks are periods of excessive numbers which indicate that the species is out of balance. The food supply, weather and other natural checks must have been very favorable for excessive increase of the species. In the ideal balanced or stabilized natural environment, outbreaks would not occur, though there would be fluctuations in numbers due to changes in weather conditions from year to year.

The plowing up of the native sod and planting present-day crops were the first and most important steps in this balance upset. It gave the then existing native species of animals new food plants and, in many cases, supplied them with a habitat nearer their optimum than nature had provided.[5] The natural result was an increased rate of reproduction with a consequent increased population of the species. Furthermore, it appears that the parasites of some of the more important insect pests require a period of years to adapt themselves to a new plant occupied by their host. This, no doubt, has been a factor in the relative unimportance of parasites in the effectual checking of most economic insects in the great plains region up to the present time. The wheat stem sawfly, for example, is said to be more heavily parasitized in wild and in other cultivated grasses than in wheat.

The change in the native flora of the prairie region is apparent to all. The fauna has been equally affected by agricultural development, insects and the smaller forms being somewhat less affected than the higher forms.[6]

Most plants and animals of the Great Plains exhibit more or less striking modifications for living there. Time does not permit a cataloging of the more striking adaptations, but many of them are common knowledge. One needs only to think of the adaptations of the grasses, tumbleweed, sunflower, cocklebur, ragweeds, of coyotes, jack-rabbits, pocket gophers, prairie-dogs, prairie-chickens and of the prairie snakes to their native habitat. The insects of the prairie have many structural adaptations which fit them for prairie life. Among these are the heavy integument of the wireworms and false wireworms, and the modifications for burrowing of many insects. These same modifications have made them all the more serious as pests of man's food plants.

[3] Charles C. Adams, "An Outline of the Relations of Animals to Their Inland Environments," *Bull. Ill. Nat. Hist. Surv.*, 1915. 11 (No. 1): 1–32.

[4] John E. Weaver and Frederic E. Clements, "Plant Ecology." McGraw-Hill Book Co., New York, 1929. (Ref. 458–469).

[5] N. J. Atkinson, "The Increase of Native Insects to Economic Importance in the Prairie Provinces," *Scientific Agriculture*, 12: 200–203, 1931.

[6] Wm. P. Hayes, "Prairie Insects," *Ecology*, 8: 238–250. Bibl., 1927.

THE GROWING OF WHEAT AND ITS EFFECT ON SOME GRASS-FEEDING INSECTS

The soil and climate of the Great Plains were early found to be well adapted to the growing of wheat. The 44-year mean annual rainfall of 27.1 inches for the whole state of Kansas is sufficient for the crop. This rainfall comes in the growing season, while the winters are usually dry with moderate temperatures. Splendid native soil fertility has made it possible in the great plains states to grow wheat in great quantity and of high quality. The large acreages and yields of the great plains states attest to the adaptation of this crop to the soil and climate of the region. It is sometimes called the "world's bread basket."

About the year 1775, an insect known as the Hessian fly (*Phytophaga destructor* Say) was accidentally introduced into the United States, presumably in straw brought over from Europe by Hessian soldiers. This creature found the opportunities in America to be all that had been said of them. The Hessian fly was a natural feeder on wheat, barley and rye in Europe, and on some of the wild grasses. Wheat, an annual grown in large acreages and a more succulent grass, is more to its liking than wild grasses. The climate of the great plains suited this creature perfectly. While in its native home it had to be content with one or two generations a year; in Kansas it could, with only rare exceptions, always have two or three generations and could in favorable seasons often produce four or five generations. Enemies were not very important factors. They could not keep up with such reproductive speed anyway, so we have in the Hessian fly an enemy of major importance to wheat. It may have changed its food plants to one of man's crops as the years have rolled around, but its environment has been changed to nearer its optimum. Nature's forces to maintain it within narrow limits of fluctuations have not yet proved effective.

As the years go on, natural enemies of the Hessian fly, aided by man, may be expected to increase in number, and probably in importance. Varieties of wheat resistant to this pest are now realities. Not to be outdone, however, the Hessian fly has appeared in strains peculiar to communities and to varieties, so it is prepared, as it were, to meet this new move.[7] It is the old contest over again between the safe-maker and safe-breaker. Man's reliance on this crop for food forces him to engage in genuine combat with the Hessian fly and to assist mother nature to force this pest into a condition of relative obscurity, as it must have been when its food, in prehistoric times, was native grasses and wild rye in Europe.

[7] Reginald H. Painter, *et al.*, "Resistance of Varieties of Winter Wheat to Hessian Fly," Kans. Agri. Exp. Sta. Tech. Bul. 27, 58 pp. 1931.

The false wireworms (*Eleodes* spp.) fed on weed seeds in the days of the old prairie. It was a short step to devouring the germinating wheat kernels in the dry soil when germination was delayed. To-day the false wireworms are major pests in the western half of Kansas and over much of the great plains region. Their adaptation to hard living conditions before man came here makes them most difficult to control.

The army cutworm (*Chorizagrotis auxiliaris*) is one of the best examples of a native grass-feeding insect which has lately become a serious enemy of many Kansas crops, including wheat, alfalfa, corn, oats and gardens. This insect is well equipped for life on the prairies. It feeds at night or during the afternoons of cloudy days. During the warmer part of the day it hides beneath the surface of the soil or trash, thereby reducing the danger from parasitism. When the brood has destroyed the vegetation in a field, it marches as an army, to an adjacent feeding ground. Observations have indicated that this species estivates in the adult stage (and probably in the larval stage also) during the hot summer, an adaptation to the high summer temperatures of the great plains area.

SOME NATIVE PRAIRIE INSECTS BECOME PESTS OF CULTIVATED CORN

Then the pioneers brought corn from Ohio and the New England states. This is another grass. It grew well in the valleys and served particularly for feed for domesticated animals. A little creature called the chinch-bug (*Blissus leucopterus* of the family *Lygaeidae*) now believed to be a native inhabitant of the great plains, found several of man's crops very much to its liking. It is significant that this insect returns to the bunch grass, its probably original or native food plant, to pass the winter. The chinch-bug spread with the growing of corn, oats, wheat and grain sorghum and forsook very largely the less succulent and tougher wild grasses. It is to-day a severe pest of these crops over most of the great plains region.

Whether a balance forcing this pest to relative obscurity, or at least to numbers comparable with other members of its family, will ever be attained is mere speculation. No other Lygaeid is so abundant or as destructive in the western hemisphere, and Imms mentions only one economic species from Egypt and one from Australia for the rest of the world.[8] Again, varieties of corn and wheat resistant to this pest may check its conquest, but, so far, it shows little disposition to yield except when forced by an open warfare of man's artificial control methods.

[8] A. D. Imms, "A General Text-book of Entomology," Methuen and Co., London. (Ref. p. 347).

The chinch-bug has few enemies. It is true that fungous diseases may develop and destroy them in great numbers, under favorable conditions, but it probably is no more serious to the chinch-bug race than an epidemic of influenza is to man. The chinch-bug egg parasite exerts a most inadequate check[9] from man's view-point, though as many as 50 per cent. of the eggs may be destroyed by it.

Wireworms (*Melanotus* spp.) fed on roots of grasses before the great plains came under man's influence, but probably were of little consequence. The stand of these perennial grasses was thick and the root system large. They could easily spare a few roots. When the sod was plowed up and the land planted to wheat or corn, wireworms were provided with more attractive food. All the worms formerly in two or three square feet of sod concentrated on each hill of corn. The small stalks, in the spring, could not withstand their attacks. These native grass-feeding insects are to-day major pests in the eastern half of Kansas.

Other pests of corn have changed from wild food plants to this nurtured crop of man grown in large acreages. The common stalk borer (*Papaipema nebris*) may develop in as many as 176 different species of plants, most of them weeds. Even to-day weedy corn fields, or fields with weedy borders are more heavily infested with stalk borers than are clean fields. The corn earworm (*Heliothis obsoleta* Fab.), a native pest, probably maintained a precarious existence on teosinte, an ancestor of our corn, in Mexico, or in pods and fruits of some wild plants of the great plains region which, in Kansas, have been almost wholly forsaken now for the farm corn crop and alfalfa. Corn is most susceptible to attacks in the early spring when the plants are small and delicate.[10] Its enemies are chiefly the grass-feeding forms which overwinter in some advanced stage of development.

Our grasshoppers are also native, so probably have been here for many centuries. They readily forsake the tough grass for the more succulent corn and alfalfa. It required no long adaptive processes on the part of grasshoppers, since they are general feeders and corn was immediately attractive. The great swarms of Rocky Mountain grasshoppers (*Melanoplus spretus*) of 1873–75, and earlier, are now mere interesting history. It is now known that this species is but a migratory or long-winged phase of one of our most common species, the lesser migratory grasshopper (*M. atlantis mexicanus*). There was an invasion of the lesser migratory species in southwest Kansas in 1913, according to Professor George A. Dean, but it has not developed since, so far as Kansas is concerned. The grasshoppers which appeared last year (1931) were not migratory, but grew up and increased in numbers in the immediate community where they did their damage. Man is now armed with some good weapons in the warfare against grasshoppers, so farmers generally do not fear them but are able to cope with them. The frequent occurrence of outbreaks shows that they are still out of balance. When the great plains are more fully under cultivation, as occurs when the land is divided into small farms, grasshopper outbreaks will likely be a rare occurrence or be absent entirely. They continue in the great plains region as one of the few surviving biological remnants of the "wild and woolly West."

[9] J. W. McColloch, "Further Data on the Life Economy of the Chinch-Bug Egg Parasite," *Jour. Econ. Ent.*, 1915, 8: 248–260.

[10] Stephen A. Forbes, "The General Entomological Ecology of the Indian Corn Plant." *Bull. Ill. Nat. Hist. Surv.*, 16 (Art. 7), 447–457, 1929.

Some Native Prairie Forms which Attack Alfalfa

From Persia to Europe, from Spain to Chile, to California, and then to Kansas came, some sixty years ago, a crop called alfalfa, lucern in Europe. It grew well, had few enemies and became a wonderful dual purpose crop. It built up the soil and furnished from three to five cuttings of good hay each year. Up to fifteen years ago it would maintain a stand on Kansas soils for ten to fifteen years. The large acreages and yields of the great plains states attest its success as an agricultural crop in this region.

The growing of alfalfa has become a difficult procedure during the last decade, and the acreage grown in Kansas has declined sharply. The average of 1930, 640,299, is a little less than half that of 1915, 1,359,498. Up to about 1905, the insect enemies were not very strong limiting agencies. Now, they so weaken the plants that disease, particularly root diseases, combined with other factors have reduced the life of the stand from ten or fifteen years to about three or four years. Several striking examples which suggest an explanation of this changing status may be mentioned.

The garden webworm (*Loxostege similalis*) had always been satisfied with weeds, chiefly pigweed (*Amaranthus*) and lamb's quarter (*Chenopodium*) but it has lately added alfalfa to its menu. In the 80's, when western Kansas was being settled, idle fields soon grew a crop of pigweed which was attacked by hordes of garden webworms. We have reason to believe that it now prefers alfalfa to weeds, since observations of the outbreaks in 1923 to 1931 have rarely shown a heavier attack on weeds than on alfalfa. If both were abundant, both were fed upon; if there were few webworms, they were largely confined to alfalfa. Its frequent outbreaks would indi-

cate that the garden webworm is out of balance because alfalfa and other crops have unbalanced primitive nature.

The pea aphid (*Illinoia pisi* Kalt.) first appeared in outbreak proportions on alfalfa in Kansas in 1921 and became at once a major pest of the crop.[11] It had formerly existed in small numbers only on garden peas and the clovers. It was instrumental in the destruction of over 100,000 acres of alfalfa in this first outbreak and it has since continued as an annual threat to this valuable crop.

The fall army worm (*Laphygma frugiperda*) has likewise found alfalfa attractive. While not fully forsaking its native wild food of grasses, particularly bent grasses and volunteer wheat during late summer, it has become an almost annual pest of this crop, at least in localities.

The corn earworm first seriously damaged alfalfa foliage in Kansas fields in the fall of 1911. This insect has always shown a decided preference for corn, certain garden crops and cotton. The silks of corn are, however, too dry in September and October to be attractive to the moths, and the kernels are too hard for the larvae. The moths then feed on the nectar of alfalfa blossoms and lay their eggs on the tender green foliage of this plant. The parasitic enemies of the larvae can find them most easily when exposed on alfalfa plants, and the percentage of parasitism is always higher than in larvae taken from ears of corn.

Pocket gophers have increased in alfalfa fields because of the fine source of food offered by the roots and because snakes and hawks, their natural checks, have been killed off; so these and many more factors, without adequate checks, are making the growing of alfalfa difficult. From the view-point of nature, the insect pests and the gophers are merely operating to restore a balance in vegetation.

Some Miscellaneous Examples of Changed Food Habits or Host Relations

The Colorado potato beetle (*Leptinotarsa 10-lineata*) was content to feed upon nightshade and horse-nettle (*Solanum* spp.) until cultivation of potatoes offered new fields of conquest. This insect has almost forsaken its wild hosts for this closely related but more succulent and more easily available crop.

The potato leaf-hopper (*Empoasca fabae*) probably was an unimportant feeder on some wild grasses in the historic past, but has since found such crops as beans, peas, alfalfa, red clover and potatoes much more to its liking. It has become a serious enemy of all its hosts by causing an injury of the type known as "hopper burn" on potatoes. No group illustrates the change from a grass and weed-feeding status to an economic enemy of crops any better than do the leaf-hoppers.

Cattle appear to be more commonly attacked by enemies and diseases than was the native bison. The latter did not have to contend with tick fever, since this disease probably was introduced, supposedly by Spanish cattle. It appears that ox warbles may be native pests and not necessarily introduced from Europe, since they have been bred from buffalo[12]. However, "The American bison do not appear to be so heavily infested as are cattle raised under similar conditions in the same region."

The vegetation of the great plains also shows a succession correlated with the progress of agriculture. Plowing up the sod makes possible the growth and multiplication of some weeds which were largely crowded out in competition with the dense sod. The common wild sunflower, the Kansas state flower, soon appropriates any idle fields. Russian thistle, according to my colleague, Dr. F. C. Gates, has attained its peak of population, and better agricultural practices are now reducing the numbers of this weed. Buckthorn (*Plantago lanceolata*) introduced as a contamination of grass or alfalfa seeds, appears to be on the increase. Dandelion and field bindweed both appear to be on the increase too. Even the eastern bluegrass has a foothold in the eastern third of Kansas and, though the climate is less suited to it than that of the North Central States, often crowds out native grass when the original sod is plowed up.

Many forms are even to-day in the process of changing from wild hosts to the cultivated crops of man. It may be that they find the cultivated crops more nourishing or more tasteful. Or perhaps it is because the cultivated plants are so much more accessible, since great areas of pure cultures occur. The sunflower beetle (*Rhodobaenus 13-punctata*) has lately been found to attack beets in Kansas. Flea beetles (*Epitrix* and *Systena* spp.) are increasingly important as pests of the early garden. So apparent is the shift from native prairie vegetation that at the Kansas State College and elsewhere especial study has been and is being made of this ecological unit or complex, since so many of our chief pests are native prairie forms which find the new order of things more favorable than the old prairie conditions.[13]

[11] Roger C. Smith and Edgar Davis, "The Pea Aphid (*Illinoia pisi* Kalt.) as an Alfalfa Pest in Kansas," *Jour. Agr. Res.*, 33: 47–57, 1926.

[12] F. C. Bishop, *et al.*, "The Cattle Grubs or Ox Warbles. . . ." *U. S. D. A. Dept. Bull.* 1369. (Ref. on p. 20), 1926.

[13] Charles C. Adams, "An Ecological Study of Prairie and Forest Invertebrates," *Bull. Ill. Lab. of Nat. Hist.*, 11: 33–280, 43 plates, Bibl., 1915; Geo. O. Hendrickson, "Studies on the Insect Fauna of Iowa Praries," *Iowa*

There is evidence that one of the chief reasons why a balance is ultimately established in nature is that resistant plants survive, while the less resistant ones succumb. Therefore, in time, a certain amount of resistance to the attacks of parasite and animal enemies characterizes the native vegetation. Cultivated crops do not show this resistance unless resistant strains are selected by man to propagate the species or unless the crop has been grown in a fairly stable environment for a long time. There is further evidence that wild plants which exhibit certain degrees of resistance to enemy attacks in nature have this resistance factor weakened by a changed environment.[14] Native prairie vegetation may be losing some of its vigor, hardiness and resistance to its enemies by the changed environment brought about by present-day conditions.

The principle of biological control is to increase the natural enemies or checks of a species by additional species of parasites, predators, or diseases, or by releasing, after artificial propagation, a large number of individuals of a common species. Some outstanding examples of biological control of noxious weeds and insects have occurred. The control of the cottony cushion scale by the Australian ladybird beetle is a well-known example among insect pests. The present-day control of prickly pear in Australia, with the cochineal scale insect and the control of the sugar cane moth borer in Hawaii, are well-known outstanding example. In these and similar instances, man has aided nature in supplying the checks to certain forms which hold them to small numbers. Eradication has never yet been attained in biological control and probably will not be accomplished. It is a graphic example, enacted dramatically in a brief space of time of a restored balance.

Man with his agriculture has upset the age-long balance of nature in the great plains region, and a new balance has not been reached. It probably is a long way off, in fact, since man is constantly changing his agriculture. Nature works slowly and not necessarily for the benefit of man. New factors under modern civilization are always being introduced which tend to postpone attainment of the new balance. Most natural checks, such as parasites, spread slowly. Man is aiding them somewhat. The native wild insectivorous birds are becoming more scarce. Their place is being taken by such forms as the English sparrow, mourning dove, grackles, crows, pigeons, robins and domestic fowls. These birds are primarily seed and fruit eaters, being only in part insectivorous, or insectivorous for part of the year. What is lost for man's welfare in one sector must be made up elsewhere by some other advances.

Insect and plant disease problems are actually increasing, both in number and severity in the great plains region. Man, the disturber, will have to employ artificial control efforts for a long time, or be seriously handicapped in his labors. This biological complex reminds us of a complicated and delicate machine in which a slight misadjustment of a part affects all the others. It is as a stone dropped into a quiet pool. The ripples travel outward on all sides and upset the grains of sand all along the shore.

State College Jour. of Sci., 4: 49–179, 1930; J. E. Weaver, "The Environment of the Prairie," Bull. No. 5, Bot. Survey of Nebr., 50 pp., 1931.

[14] J. W. McColloch, "The Resistance of Plants to Insect injury," Bien. Rept. Kans. State Hort. Soc., 37: 196–208, 1924.

VIRUSES[1]

By Dr. T. M. RIVERS

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THIS is an age of extremes. Very tall buildings, exceedingly large ships and unusually fast automobiles are indicative of modern trends. Moderation no longer satisfies. This desire for the superlative has taken possession of workers interested in infectious maladies, and now it is a common occurrence to hear talk about the minutest incitants of disease, namely, those that penetrate the "very finest" and "most impervious" filters. Extremely high buildings are not necessarily beautiful and profitable. Nor is the fastest mode of travel always the safest and most enjoyable. Large incitants of disease may be just as injurious to their hosts as are extremely minute ones. Yet the fact that a building is higher than all others and that certain etiological agents of disease are too small for resolution by means of a microscope lends an air of importance or mystery to the objects possessed of such unusual characteristics.

The sudden realization on the part of many workers that certain incitants of infectious disease may be very small and that types of infectious agents different from those already known may exist undoubtedly accounts for some of the present interest exhibited in viruses. These agents and the diseases caused by them are no more important now than they were formerly. Nevertheless, a concerted curiosity has served to focus attention upon them at this time. With this increased interest there have appeared in the literature many fantastic statements and unwarranted conclusions regarding the viruses. It is concerning some of these that I wish to make a few comments.

[1] Presidential address, the American Society for Clinical Investigation, Atlantic City, May 2, 1932.