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FOSSIL INSECTS.*

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In these serious days, it seems just a little grotesque that I should cross half a continent to address you on a subject so remote from the current of human life as fossil insects. The limitations of our society do indeed forbid such topics as the causes of the war or the evil effects of intercollegiate athletics; but I might have chosen to discuss lice or mosquitoes—any of those insects whose activities have before now decided the fate of nations. My excuse for avoiding these more lively topics only aggravates the offense, for it is the fact that I have never given them adequate attention, but have in the past ten years occupied myself with matters having for the most part no obvious economic application.

There is, however, another point of view. Many years ago I had the good fortune to meet the eminent ornithologist, Elliott Coues, at Santa Fe. We spent a considerable part of the night discussing a variety of subjects, from spiritualism to rattlesnakes, and when we parted he made a remark which those who knew him will recognize as characteristic. He said, "Cockerell, I really believe that if it had not been for science, you would have been a dangerous crank!" Surely experience and history alike confirm the essential sagacity of the observation, as applied not merely to your lecturer, but to mankind in general. How often has our poor human race exhibited the qualities of a dangerous crank, owing to the lack of those which devotion to science may stimulate! Has it not been so

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in Europe in these dreadful days? It is true that science is being accused as the handmaiden of war, is blamed for the many diabolical inventions for taking human life; but these things are aside from the great current of scientific thought, and it would be equally just to accuse language, which is at the very root of human progress, because forsooth it has been the vehicle of every hateful emotion.

The pursuit of science, by which we mean the effort to understand nature, is akin to religion, because it enables us to see the world as part of the universe and ourselves and our affairs as particular examples of universal phenomena. We do not thereby lose our self respect; on the contrary, it should be increased by the consciousness of having a part in the affairs of the cosmos. It is some such feeling as this, not usually defined in words, which keeps the naturalist to his task. People ask him, why do you labor over that microscopical animal, of no apparent interest to any one? They might as well ask a bricklayer why he thinks it worth while to lay any single brick of some mighty building.

The general sense, the pious belief, that every part of the scientific structure is worth while, has been greatly heightened in recent years by researches in genetics. It is a marvelous thing that we can reason from Mendel's peas to human life; that Jenning's protozoa should be significant for the study of sociology. Thus we come to the conviction that even a fossil cockroach from the coal mines of Pennsylvania has some story to tell which may serve us in our day. Entomologists are not as humble as they were in my young days, but I fear they do not yet appreciate the full significance of their science in relation to the philosophy of life. The enormous variety of insect life, exhibiting innumerable adaptations to all sorts of conditions, gives us unparalleled opportunities. What New York is to the sociologist, the class Insecta must be to the naturalist. A single species of insect, *Drosophila melanogaster*, has enabled Morgan and his associates to largely reconstruct our ideas concerning the mechanics of heredity; to give us well ascertained facts in place of much vague speculation.

It is, however, from the *comparative* morphology and physiology of insects that we may expect to learn most about the phenomena of evolution. I recall being present several years ago at a meeting at Boston, when Professor J. C. Bradley exhibited a number of figures of hymenopterous wings, and offered some opinions concerning the evolution of the venation. In the discussion which followed, the criticism was made that all the species concerned were living ones, that obviously they could not be thought of as ancestral to one another, and consequently any attempt to see in them a true evolutionary series must be futile. This sounded reasonable, but it did not take into account the fact that while *species* may all be recent *genera* of insects are old, and of extremely different antiquity. This is one of the lessons we have learned from the study of fossil insects, and it teaches us that the existing insect fauna is extremely rich in ancient types, which do really illustrate evolutionary sequence. The reason for this is rather obvious. The stream of insect life branches in a complex manner and owing to the enormous diversity of possible adaptations, resulting from the diversity of physical conditions, of food and of enemies, very many of the products of evolution have been preserved without important modification. This is especially striking when we regard *characters* rather than *species*, and observe differences in the minute structure of the tegmina of Palæozoic cockroaches, corresponding with similar differences to be found in their living representatives. Just as the infinite variety of higher animal life has been built up from a scarcely altered fundamental series of *tissues*, so families, genera and species have arisen not so much from entirely new developments, as from the shuffling of ancient characteristics. There is, of course, no doubt that definite progressive evolution has taken place among the insects just as among the vertebrates; thus the greatly modified mouth-parts of bees and butterflies, adapted for sucking the nectar of flowers, certainly came into existence after the Palæozoic, and when plants with suitable corollas had developed or were developing.

There is no doubt that the Mesozoic, the period of the rise of the higher plants, saw a remarkable development of insect life, concerning which we know too little, owing to the relative scarcity of fossils. It does not appear, however, that there is much if any innate tendency to progress, without reference to changing conditions. During the Tertiary epoch there seems to have been little forward evolution, and in the north temperate regions we may detect a very perceptible contraction and impoverishment of the fauna since the Miocene. In the absence of a progressive movement, there has nevertheless been much of the shuffling already mentioned, producing a great mass of specific forms, while many genera have become extinct. Aside from these general questions, we may value the evidence afforded by fossil insects for the light thrown on geology and paleogeography . In the first place, although the *genera* of insects are of long duration, the *species* appear to be short lived. The best evidence for this opinion comes from the fact that strata supposed by the geologist to be of nearly or quite the same age, often contain insect-faunulæ in which the species are all distinct. This may be partly due to different ecological conditions and to migrations, but it certainly is due in part to the comparatively rapid evolution of insect species. This is especially proved by the Pleistocene beetles studied by Scudder, which are closely allied to modern species, yet distinct. Professor Wickham is now engaged in the study of many additional Pleistocene beetles, and though his work is not finished, he kindly informs me that "they seem to be pretty nearly all different, subspecifically at least, from those of today."

Owing to the complexity of insect life and the facilities these animals have for getting about, faunæ are constantly in a state of flux, species locally dying out, and others coming in. Thus there can be little doubt that complete collections made in any locality at intervals of one hundred years would be appreciably different; except perhaps in the tropics, where conditions are likely to be more uniform. It is doubtless on account of this fact that we not rarely find non-functional examples of "mimicry," which are offered as obstacles to the view that mimicry has any adaptive significance. It is evident that the almost kaleidoscopic insect fauna must present characteristics which are to be understood in relation to the past rather than to the present. It results from all these considerations that fossil insects, when they can be obtained in any numbers and from different levels, afford a very delicate index to the details of stratigraphy, probably surpassing in this respect every group of organisms except mammals, which are not available for the purpose until we reach the Tertiary. The obvious objection to the use of insects in this manner arises from their comparative scarcity; but this has been exaggerated, and every year brings to light new localities. In particular, the Pennsylvanian (Upper Palæozoic) coal bearing strata of Maryland, Pennsylvania and West Virginia have lately been found by Mr. H. Bassler to contain numerous faunulæ, mostly cockroaches, which I have been permitted to study. Scudder and Handlirsch had already observed that practically every Palæozoic locality yielded different species, and I have also found this to be the case. Considering the number of species and localities discovered by Mr. Bassler in a couple of years or so, we may reasonably expect eventually to have a very good detailed knowledge of the insects of the Pennsylvanian, and thereby have the means of elaborating a very accurate stratigraphy of the anthracite coal region. The tendency of all these studies is to enlarge our conception of the duration of the Pennsylvanian, which must represent an enormous amount of time. The main outstanding question now is, can we not only distinguish all these cockroach faunulæ—as we certainly can—but also place them, from the evidence afforded by the insects alone, in the right order? In other words, can we recognize a direct forward evolution, or are we again confronted by a shuffling process? Before attempting to answer this, we must get rid of the idea that regular progressive development necessarily occurred, and only waits to be detected. In the Tertiary, were it possible to restore the faunæ of a million years ago to life, and place them beside those existing now, there are certainly several groups, at least, in which no entomologist could distinctly affirm which was the more primitive. The best he could do would be to point out that whereas both lots contained archaic genera, there were rather more of these in the older series; and to do this he would need very complete materials.

Returning now to the Palæozoic fauna we find, as Handlirsch has pointed out in several papers, that insect life begins, so far as we know it, with that remarkable group called Palæodictyoptera. The so-called Silurian insects are clearly valueless, and the exact age of the oldest Palæodictyoptera is still a matter of dispute; Mr. G. F. Matthew still adheres to the opinion that the remains from St. John, New Brunswick, are of Devonian age. He points out that cockroaches are entirely absent, that Devonian genera exist among the accompanying plants, and that a later (Mississippian) facies is due to the fact that the deposits represent an old delta plain, whereas other known Devonian plants are from what was hilly country or sea-coast. On the other hand Kidston and David White, judging from the plants, would refer the beds to the Carboniferous, even later than the Mississippian. Leaving these matters undecided, there are still some important facts which admit of no dispute. In the first place, the insects, like the higher flowering plants, first appear on the scene in a highly developed condition. It is true that the Palæodictyoptera are very primitive as compared with our modern Lepidoptera, Hymenoptera or Coleoptera, but in their own particular line, they represented a wonderful development of insect life.* There was evidently great variety of form and structure, while many of the species reached an enormous size. The anterior wings of *Archæoptilus gaullei* Meunier are estimated to be 18 cm. long, and as the distance between the wings is 24 mm., the total expanse is 384 mm.—over 15 inches.† Truly, there were giants in those days! This exuberant type flourished during a period *before the rise of the Blattids*, but extended into the Pennsylvanian, where, as at Mazon Creek, Illinois, it is accompanied by a rich fauna of Protorthoptera and Blattoids. It existed equally in Europe and North America, and in both areas gradually disappeared during the Upper Carboniferous or Pennsylvanian. The disappearance of the Palæodictyoptera is coincident with the rise of the Blattoids; and in America, at least, we soon come to a period when the Blattoids were dominant, to the total exclusion of Palæodictyoptera, and the great reduction of all other insects. This lasts to the end of the Pennsylvanian, and perhaps into the Permian; but in the Permian strata of Kansas, in which Sellards obtained a very rich insect fauna, Blattoids are in the minority, and other insects are numerous. Thus we have certainly three great periods, so far as the insects are concerned; one prior to the appearance of Blattoids, one during which the Blattoids and Palæodictyoptera and Protorthoptera existed together, and one during which the Blattoids were dominant almost to the

*Reconstructions of these insects must not be taken too seriously. In his very valuable and suggestive paper on the Ancestry of Insects (Am. Jn. Sci., Nov., 1916), Mr. J. D. Tothill copies a couple of figures from Handlirsch, which that author states to be diagrammatic reconstructions. Mr. Tothill, however, makes Handlirsch's hypothetical and reconstructed Palæodictyopteran larva a *Stenodictya*, and proceeds to discuss the larva of that genus, as if it were well known.

†The largest known insect, ***Meganeura monyi*** Brongniart, from the Upper Carboniferous of Commentary, France, is stated to have had an expanse of fully 70 cm., or about 2 ft. 4 inches. Handlirsch refers it to the Protodonata, a type prophetic of our modern dragon-flies.

exclusion of other types. If we go into the Permian, we have still another great period, in which the insects were smaller, and becoming more diversified, with the Blattoids in the minority.

This does not by any means exhaust our catalogue of sequences. Scudder in 1896 gave an elaborate table showing that during Upper Carboniferous and Permian time there was a fairly regular decrease in the size of cockroaches, so that if one had a number of faunulæ, the average size of the members would be an index to the relative ages of the strata. Since Scudder's time some of the opinions of geologists have changed, and from the recent material which has come in, I do not believe that this class of evidence is as valuable as it seemed to be; yet it is probably not without significance. More important in some respects is probably the relationship between the Archimylacrid and Mylacrid Blattoids, two groups easily distinguished as a rule by characters of the venation. The Archimylacrids appear to be the older, and these, along with the Palæodictyoptera, abound both in Europe and America. The Mylacrids, on the other hand, are essentially American, and appear to have developed during a period when there was no land connection between the Old and New Worlds. The proportion of Mylacrids in a given fauna is probably highly significant for stratigraphy; and the whole group emphasizes the fact already suggested by other evidence, such as that obtained by Petrunkevitch from a study of the Arachnids, that during middle Pennsylvanian time, at least, the evolution of the American fauna was wholly independent of that of Europe. Thus, as we investigate these matters, we do seem to observe a distinct procession of events, which cannot be without significance for geology or evolution.

The Permian, or closing period of the Palæozoic, was marked in North America by an elevation of the land surface and a general reduction of temperature. This continued into the Mesozoic. The new conditions appear to have been unfavorable to Blattoids, and to have given opportunity for the development of diverse types of smaller insects, many of which passed their early life in fresh water. There was at the same time a remarkable development of terrestrial cold-blooded vertebrates. The new start thus made probably may be taken as representing the foundation of the modern insect-fauna, though several important orders did not appear until much later. The appearance of the Coleoptera very early in the Mesozoic, with perfectly characteristic elytra having sometimes quite modern-looking color-patterns, is surprising and not at present to be explained. The Diptera, Lepidoptera and Hymenoptera all came in later. The Upper Mesozoic or Cretaceous strata have as yet proved extremely poor in insect remains; less than fifty species are known, and most of these are quite worthless objects. This is very unfortunate, as it is probable that during this period most of the modern families of insects had their origin. Nothing would do more to throw light on the relationships of living insects than the discovery of a rich Cretaceous fauna. It is surprising that among the numerous Cretaceous plants, for example in the Laramie of Colorado, where the preservation is so good that it is sometimes possible to peel off the epidermis of leaves, insects hardly ever occur. A Blattoid (*Stantoniella*) was indeed found in the Judith River beds of Montana, but it remains unique. An astonishing find was that of an apparent Fulgorid (*Petropteron*) in the Pierre Cretaceous, a marine formation, at Boulder, Colorado. It had fallen into the sea, and been buried in the mud of the littoral zone. The most hopeful discovery, so far, is that of a very good Trichopteron (*Dolophilus*, a genus still living) in Upper Cretaceous amber in Tennessee. If an insect fauna can be found in this amber it will be of extraordinary interest and value.

Attention should be called to a very interesting paper by Mr. R. J. Tillyard, published this year by the Queensland Geological Survey. He describes a number of Australian fossil insects, and in particular a supposed Lepidopteron, *Dunstania pulchra*, from the Trias, said to be the oldest Lepidopteron known. This has since been discussed by Meyrick, who concludes that it may be Homopterous, but cannot be Lepidopterous. As he remarks, the thickened wing-margin is unlike that of Lepidoptera. There is certainly a suggestion of a Cicada-like form in the region of the cubitus.

The Tertiary epoch represents perhaps four million years, certainly much less than half the Mesozoic. At the close of the Mesozoic there was an uplift similar to that marking the Permian, and during Tertiary time this has been maintained, with minor oscillations, while the continental climates in north temperate regions have become colder and more arid. Thus in Colorado the end of the Cretaceous marks the emergence of the country east of the mountains from the sea, and the transitional marsh conditions, with an abundance of luxuriant vegetation, produced the deposits now yielding the Laramie coal. About this time the great dinosaurs died out, and the higher mammals began to show what they could do. The story of Tertiary mammalian life is a wonderful one, and our knowledge of the details is now very considerable. Reasoning from analogy, we might expect that the Tertiary would show a progressive movement in insect evolution comparable with that marking the end of the Palæozoic and beginning of the Mesozoic. It is a fact that on comparing the Tertiary insects with the Mesozoic, there are differences in part resembling those observed among the mammals. The Tertiary insect fauna is essentially modern, indeed it may be said that we have it still with us. It is far richer and more varied than that of the Mesozoic, especially in such groups as Lepidoptera and Hymenoptera. In the flora, we have a remarkable expansion and development of the herbaceous type, but no radical modification comparable with the origin of the higher flowering plants. So also among the insects, we have a great increase in variety, an immense series of adaptive modifications, but nothing to be compared with the origin of the Coleoptera, Diptera, Lepidoptera and Hymenoptera. Has nature partly exhausted her possibilities, new adaptations being limited owing to the very success of the older ones?

As students of particular groups of insects, we are keenly interested in the evolution of the modern families and genera. As we look at the known Tertiary forms, we are impressed by the number of genera identical with or closely related to those now living, and the extreme scarcity of extinct families, or even subfamilies. There is this to be said, however, that the oldest extensive fauna in Europe is that of the Baltic Amber, in the Lower Oligocene. Back of that, during the vast period represented by the Eocene and Paleocene, there are only a few scattered remains, the most instructive being a beautiful dragon fly (*Triæschna gossi* Campion) from the Upper Eocene (Bagshot Beds) of Bournemouth. In this country we are more fortunate, since the extensive deposits of Green River in Wyoming and White River in western Colorado and eastern Utah are certainly Eocene, not Oligocene as has been sometimes supposed. There are also other Eocene localities, such as that near Rifle, Colorado; and quite recently a small series of Coleopterous elytra has been obtained in Colorado in beds which are probably quite near the base of the Tertiary. The value and importance of these older Tertiary insects has never been appreciated; Scudder, who described nearly all of them, was not aware of their relative antiquity. In his work on the Tertiary weevils Scudder brings out very clearly the radical difference between the Florissant Fauna and what he calls the Gosiute Fauna, although "the deposits of both (Florissant and the Gosiute Lake) are presumably of Oligocene age." When we consider that according to the best information we now possess. Florissant is Miocene and the Gosiute Lake Eocene, all surprise at the absence of species common to both vanishes.

The Rocky Mountain Eocene insects present a rather remarkable assemblage, not so much on account of what is present, as for the absence of important groups. Coleoptera, Diptera and Hemiptera are numerous, but prevailingly small. There are a few Orthoptera and some good Odonata. A few very poorly preserved ants were described by Scudder, together with some parasitic Hymenoptera and a good sawfly; but no bees have ever been obtained, and there is only a single fossorial wasp. No Lepidoptera have yet been seen. Perhaps the most interesting Dipteron is an Oestrid, represented by numerous larvæ.* Various families of the higher Diptera were represented by genera which still exist. It is possible that the conditions of deposition partly explain the character of this Eocene fauna, or series of faunulæ, and it is reasonable to expect that further collecting will greatly modify the statistics. At the same time we are lead to ask whether the complete modernization of Tertiary insect life had taken place at this early date; or rather, granting that the fauna so far as it goes is quite modern in aspect, whether the exuberance of types so characteristic of later times had yet developed. The condition of affairs may, in short, have been analogous to that observed in the Mammalia, which had by this time established the modern outlines, but had much development and diversification

* Dr. J. Bequaert calls my attention to the resemblance between these larvæ and those of the African genus *Dermatoestrus*. The imago of *Dermatoestrus* is unknown.

still ahead. The parallel is of course not exact, since insect genera are much more stable and long lived than those of mammals.

The fauna of Prussian Amber, of Oligocene age, is extraordinarily rich and beautifully preserved, the specimens resembling mounts in Canada balsam. In the museum at Konigsberg are over 100,000 specimens, while many exist elsewhere. Fake specimens are occasionally seen in collections, or specimens supposed to be in amber, but really in African Copal, of post-tertiary age. Putting aside all these, the perfectly genuine Oligocene amber collections are enormous, though only partly worked up. Ulmer, in a most remarkable work, has monographed the Trichoptera; Wheeler has done a like service for the ants; Meunier has described a great series of Diptera, and other authors have discussed smaller groups. Edmund Reitter has made a preliminary survey of the Coleoptera, indicating the recognisable families and genera, and a considerable number of apparently new genera not yet described or named. On looking over the lists, one notices first of all the richness of the fauna, the great abundance of genera and species. During mid-Tertiary times, the climate of the present Holarctic region was warmer than at present, and conditions seem to have been exceptionally favorable for an abundance of insect life. Since that time, the glacial period, or rather succession of glacial periods, has destroyed or driven out very many types, so that today we dwell in a relatively impoverished world, so far as the North Temperate region is concerned. Another remarkable thing is the lack of progress exhibited in the two million years or so since the time of the amber. Wheeler, referring to the ants, says that since the amber "the family has not only failed to exhibit any considerable taxonomic or ethological progress, but has instead, suffered a great decline in the number of species and therefore also in the variety of its instincts, at least in Europe." Ulmer, speaking of the Trichoptera, says that the amber fauna is quite as highly developed as that of modern times. The presence of numerous extinct genera in all groups bears witness rather to the faunal contraction already mentioned than to any uniform and general advance of organization. There are, indeed, some archaic genera, but such also exist today. It must be said, however, that the bees, which I have studied, *all* belong to extinct genera, and on the whole are distinctly less advanced than the higher modern ones. There are, however, many modern genera of bees more primitive than any yet found in amber. Meunier's catalogue of amber Diptera is remarkable for the great numbers of Tipulidæ, Cecidomyiidæ, Mycetophilidæ, Chironomidæ, Psychodidæ, Phoridæ, Empididæ, and Dolichopodidæ. On the other hand, Asilidæ, Bombyliidæ, and many families of higher Diptera are very rare or absent. This looks at first like a certain indication of the relatively undeveloped character of the Dipterous fauna of the Oligocene, and is quite in line with the evidence from the much earlier Eocene of North America.

It will be noted, however, that precisely those forms are present which would most easily and probably be caught in the amber, and there is no possible doubt that the list fails to represent large elements in the fauna. This is well shown by the scarcity of Lepidoptera, which undoubtedly abounded in those days. The Florissant Coleoptera, of Miocene age, much later than the Baltic amber, are remarkable for the prevailingly small size of the species, and here we cannot so easily ascribe the peculiarity to the method of preservation. It would doubtless be true, under almost any conditions, that the larger and stronger forms would be most likely to escape the destructive influence; yet we are left with a residue of feeling that the average size of the insects actually was less than at present. Many of the larger species in the present fauna represent essentially southern, or even tropical groups, and it may well be believed that though their ancestors existed in Oligocene and Miocene times, they had not yet spread northwards. The very impoverishment of the fauna during glacial times, with the subsequent amelioration of the climate, may have given opportunities to southern types, which during the mid-Tertiary were barred out by an already rich and aggressive fauna occupying the territory.

Also Oligocene, but perhaps later than the amber, is the rich deposit at Gurnet Bay, in the Isle of Wight. The specimens are preserved in solidified mud, absolutely without compression. The materials are of particular importance, not only as coming from a distinct locality, but on account of the quite different medium in which they are preserved. So far, 25 Diptera, 4 dragon flies, 8 ants, 1 Diapriid, 1 wasp, 4 Homopteron, 1 Lepidopteron, 2 termites, a *Sisyra*, a *Raphidia* and an *Aeolothrips* have been described. The list is not long enough to prove much, but the series has a modern aspect. The ants include species of *Oecophylla*, now especially characteristic of tropical Asia and Australia; while the termites belong to the primitive Australian genus *Mastotermes*. The wasp, assigned to the Philanthidæ, may perhaps belong to the Mutillidæ (Myrmosinæ), as Mr. S. A. Rohwer has suggested in correspondence. I cannot recognize any of the species as being identical with those in amber. A very large collection of these Gurnet Bay insects is in the British Museum; and while the majority cannot be determined, it is certain that among the 2,500 specimens there are sufficient good ones to give us a fair idea of the fauna. I examined 170 of these specimens and found twelve describable new species, not including the Coleoptera, which were numerous. At this rate, the whole collection may perhaps be expected to yield at least 200 species. I described 33 species from the Lacoe collection in the U. S. National Museum; these came originally from the Brodie collection, which is now in the British Museum. Although they were supposed to be "duplicates," they were apparently selected with judgment, and as no serious attempt has ever been made to sort the species among the Gurnet Bay fossils, it is very probable that many of the Lacoe series are not represented in the larger collection. All the Gurnet Bay insects of which I have any knowledge were collected many years ago by the Rev. P. B. Brodie, and I do not know whether the deposit is still workable. Arrangements are being made at the British Museum to have the Gurnet Bay collection worked up by various specialists; Mr. Donisthorpe has already undertaken the ants.

Baltic amber is not the only source of amber insects. Amber is found on the east coast of England, and specimens containing insects are in the museum of Cambridge University. One piece contains a couple of modern honey bees, and is, I fear, a fake; but some of the others look genuine. The species still await critical study and description. Shelford described some Blattids from Miocene amber obtained at Stettin; one of these he could not distinguish from the living *Euthyrrhapha pacifica* (Coquebert), which is at present found in South America, Africa and Polynesia. Sicilian amber, also of Miocene age, and therefore much later than Baltic amber, has yielded some very interesting insects, especially a remarkable series of ants and a Meliponine bee.

Very recently, Mr. R. C. J. Swinhoe has sent me many specimens of Burmite, or Burmese amber, containing insects. This material occurs in clay beds of Miocene age, but it is evident that the amber was washed into them from higher levels, and it is not impossible that it is much older. The insects, so far as yet examined, have rather a primitive aspect, but the number of species as yet available is small. I find a Termite (*Termopsis*), a Psocid (doubtfully referred to *Psyllipsocus*), an Hemipteron of the interesting genus *Enicocephalus*, a *Trigonalys*, two extinct genera of Evaniidæ, both very small, an extinct genus of Empididæ, a *Sciara* and a species of the Psychodid genus *Trichomyia*. It is expected that more of this amber from Burma will be available, and we may ultimately get a good idea of a Tertiary insect fauna in tropical Asia.*

It is not necessary to review the quite numerous deposits containing Miocene insects in Europe, but we cannot overlook our own wonderfully rich Florissant shales. A short distance west of Pike's Peak, resting on a base of granite, is an ancient lake-basin containing laminated shales full of insect and plant remains. The preservation of the specimens is often excellent, even such minute and fragile creatures as Aphids being represented by numerous recognizable genera and species. The number of described species is now about 1300; by far the largest Miocene insect fauna known in the world. The corresponding European deposit, at Wangen on the Rhine, has 465 described species, but many others remain undescribed in the University at Zurich. It is certain, however, that were all the Wangen fossils worked up, the series would still fall far short of that of Florissant.

The presence of certain types which probably reached America from the Old World, and the absence of any distinct Neotropical element, suggest that the Florissant beds were laid down subsequent to the beginning of the migration from Asia by way of what is now Behring Strait, but before North and South America were connected; that is to say, in the latter half of the Miocene. Should mammals be found at Florissant, early forms of the elephant group may perhaps be expected. Perhaps the most remarkable of all the Florissant insects is the genus *Glossina*, today known as an inhabitant of tropical Africa,

* Since this was written a new lot has come to hand, including many species, one an Elaterid beetle nearly 20 mm. long.

where it carries parasites which cause fatal diseases to man and animals. No less than four species of tsetse flies have been found fossil at Florissant; and the extraordinary thing is, that these alone represent the higher Muscoids in the fauna, there being no true Muscidæ, no Tachinidæ, Dexiidæ or Sarcophagidæ. Anthomyiidæ and various acalyptrate families appear to be rather common. Bombyliidæ are abundant and very varied, consisting of twelve genera now extinct, a doubtful *Geron*, and a species of the living but rare and widely scattered genus *Dolichomyia*. It is possible that the Bombyliidæ then occupied, as parasites, the position now chiefly taken by the Tachinidæ. The Anthracine Bombyliids, now so prominent in the Rocky Mountain fauna, appear to have been entirely absent; their advent during the later part of the Miocene may have been one of the main causes of the disappearance of so many of the Florissant genera, though the competition of the Tachinids must also have been important. We get here a glimpse of the drama of insect life; the development of a series of types occupying a definite place in the scheme of nature, and their replacement by other more vigorous or aggressive forms, coming from some remote region of the world. Another astonishing Florissant fossil, discovered by Mr. S. A. Rohwer, is a species of Nemopteridæ, those remarkable insects with long narrow hind wings, expanded at the end. I could not separate the species from the Old World genus *Halter;* but Navas, after examining my type, concluded that a distinct genus was indicated. He accordingly named it after Pere Marquette, and the insect becomes *Marquettia americana* (Ckll.)

Professor Wickham, who has occupied himself with the Florissant Coleoptera for several years, is now able to enumerate nearly 570 species; his latest paper, on the Elateridæ, records 43 members of that family, as against 23 species described from all other deposits of the world combined. The beetle fauna has an entirely Holarctic facies, though extinct genera are fairly numerous. The Rhynchophora are extraordinarily numerous; very much more so than in the Miocene of Europe. On the other hand, the Chrysomelidæ are relatively scarce, and there are no Histeridæ or Cicindelidæ. Among the causes which have led to the contraction of the Rocky Mountain weevil-fauna since the Miocene, must evidently be the great reduction in the number of genera of woody plants; the total elimination of the figs, magnolias, chestnuts, elms, *Ailanthus*, and various other kinds of trees. This change in the vegetation would necessarily affect thousands of plant-feeding insects, while the climatic changes giving rise to it would favor the increase of many genera. Thus, the more we study the Miocene insects of Colorado in comparison with those of today, the more evident it becomes that the differences observed are due, not so much to any definite forward evolution, as to migrations and the extinction of a certain number of genera. It is a very striking fact, however, that in particular groups, such as Aphididæ and Bombyliidæ, the genera are practically or quite all extinct, while in others they are little different from those now inhabiting North America. The most conspicuous contrast between Florissant and the Baltic amber is seen in the bees. All the amber bees are of extinct genera; but of the 28 species of Florissant bees, only eight belong to extinct genera. Wheeler has recorded evidence that as far back as the Baltic amber, perhaps a couple of million years, the ants had many of the specialized habits they have today. Similarly at Florissant, we find that various kinds of gall-insects made galls as they do now, and leaf-cutting bees cut leaves in exactly the same manner.* Species of *Ficus*, both leaves and fruit, have been uncovered; and also a genuine fig-insect, which doubtless brought about fertilization as fig-insects do today.

From Florissant times up to the Pleistocene, we have no knowledge of the character of the North American insect-fauna. From the Pleistocene, however, a fairly large assemblage of beetles is known, and there is every reason to suppose that it will be greatly increased when more systematic search is made. The latest discovery of Post-tertiary beetles has been made in Florida; some specimens which reached me from Dr. E. H. Sellards the other day have been forwarded to Professor Wickham, who will report upon them.

The study of fossil insects adds another dimension, as it were, to the edifice of entomological science, and throws light on the broad problems of evolution. When insect remains in the

*Berry, in his excellent work on the Lower Eocene Floras of S. E. North America, recently published by the U. S. Geological Survey, figures a leaf of *Icacorea* showing numerous holes, and remarks that may indicate the work of a species of Megachilidae. The work is, however, entirely different from that of the leaf-cutting bees, and it would be a mechanical impossibility for any one of them to riddle a leaf in the manner shown.

rocks appeared to be few and scattered, the lessons to be learned from palæoentomology could not be clearly perceived. Today the situation is very different, and evidently our present knowledge of the subject is small compared with that which the next generation will possess. Not only are new localities being discovered every year, but the old ones are for the most part, at least, still as fertile as ever. There already exist in museums many hundred, perhaps thousands, of species of fossil insects which await description; many collected years ago, and strangely neglected. Entomologists certainly have the excuse that they have been more than busy with the existing insects, and with economic problems; but one might have expected that the greatest and most progressive nations would have produced a fair succession of students of fossil forms. England, until now, has neglected the splendid Gurnet Bay collections preserved in the British Museum; in America the Florissant beds were long unworked, and there are still museums where Florissant insects are preserved, without any steps being taken to get them described. In Germany, the revival of active interest in the amber fauna is comparatively recent, and on visiting the famous Oeningen deposit a few years ago, I found it had been neglected since the time of Heer. At Zurich, where Heer's types, and many undescribed species which he did not live to publish, are carefully preserved, there is no one to continue the work. Handlirsch in Vienna has produced his great work on Fossil Insects, which enormously facilitates the labors of all who are interested in the subject, and there is indeed much evidence of a new birth of palæoentomology; but many more collectors and students are needed.

Not only this, but for the development of what we may call the philosophy of entomology, of that historical perspective without which the most elaborate monographs are seriously inadequate, it is necessary that the ordinary working entomologist should take account of the fossil members of his group. It is truly extraordinary that when Scudder published his great monograph on the Tertiary Insects of North America, hardly any attention was paid to it, and for many years there was practically no one to give it, or any part of it, the serious and critical study it deserved. The organization of biological and entomological knowledge is rapidly advancing in these days of increasing scientific activity. We like to believe that we live in the Age of Science; but there are many more lunatics than scientific investigators in the country. When science really comes to its own, when the spirit of science permeates the community, there can be no doubt that the whole face of our civilization will be changed. If, however, the material advance due to science is unaccompanied by a corresponding moral elevation; if scientific discovery merely sharpens the edge of the weapons of discord, the disruptive forces in society, it can only hasten the collapse of human civilization. Thus we understand why, in the warring countries of Europe, every effort is made to keep alive the sacred flame in the temples of pure science. Academies meet, journals are published, researches are continued, not from any indifference to the events going on around, but to preserve, so far as may be, the habit of mind which rises above the dust of conflict, and looks toward the future of mankind.

If Europe can do this in war, how much more should America in peace; unless, indeed, we are obliged to confess ourselves relatively incapable of the larger vision. The Republic of Science is the greatest of all republics, and those conscious of having a part in the common task of the world cannot cease to co-operate, even in times of war. Thus, in a large sense, philosophical entomology, entomology which recognizes the entire scope and purpose of our science, is the most serviceable, the most truly economic, of all. It ceases to be mere science, and blending with those deeper feelings which we call religion, transforms our whole point of view.

APPENDIX.

HYMENOPTERA.

Protofoenus new genus (Evaniidæ).

Antennæ long, filiform; head broad, eyes rather small; mandibles strongly incurved and sharp apically, apparently quite simple; legs slender, hind tibiæ long and slender, not at all clavate; abdomen of female thick and rather short, with a rather long very slender ovipositor directed obliquely upward; wings ample, venation of anterior pair nearly as in *Foenus*, with the same kind of first discoidal cell, in the same position, but the apical side of submedian cell oblique, not bent in middle, and the basal side of second discoidal as shown in figure. The second antennal joint is distinctly modified, broadly pyriform. The scutellum is elevated, rounded in lateral profile.

Protofoenus swinhoei n. sp. (Fig. 1, A, anterior wing; B, abdomen; C, hind leg; D, head; E, base of antenna; F, mandibles).

Length about 4.6 mm.; wings translucent, the apical half suffusedly dusky, stigma and nervures fuscous; antennæ, face and front black, but the broad cheeks entirely honey-color; thorax and abdomen black; legs mainly dark, but hind femora pallid except at base, and hind tibiæ except at apex; the minute claws appear to be quite simple.

In Burmese amber; received from Mr. R. C. J. Swinhoe.

This remarkable little insect caused me much perplexity. It seemed to resemble the Braconidæ, but it was seen to possess a very well developed costal cell. From a sketch of the venation, omitting the characteristic first discoidal cell, which I had not at first clearly seen, Messrs. Rohwer and Gahan were positive that it could not be a Braconid, and suggested affinity with the Proctotrypidæ. On further study, viewing the specimen at different angles and in different lights, I was able to make out all the characters which placed it positively in the Evaniidæ, nearest to *Foenus*, from which it differs in the shape of the abdomen and form of the hind legs. It is a primitive type related to *Foenus*, possibly the ancestral form of that genus, although on superficial examination one would not suspect the relationship.

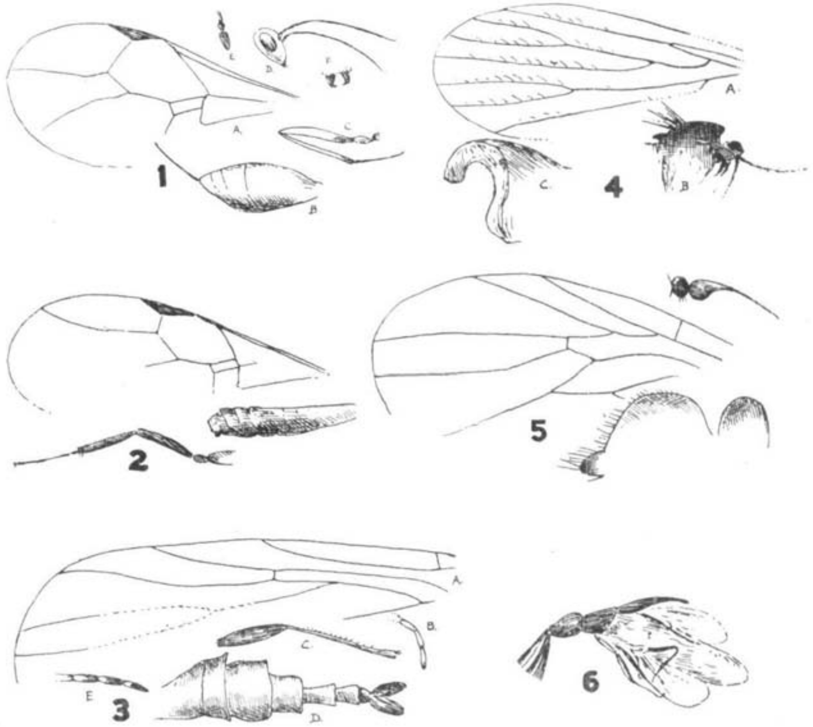
Hyptiogastrites new genus (Evaniidæ).

Related to *Hyptiogaster* but still more primitive; marginal cell truncate at base; first discoidal small, not produced apically; head much broader than thorax; antennæ long, filiform, apparently as in *Evania;* male abdomen cylindrical; legs of moderate length; claws small; hind tibiæ thickened, tarsi long, the hind femora, tibiæ and tarsi subequal; hind spurs short.

Hyptiogastrites electrinus n. sp. (Fig. 2, anterior wing, abdomen and hind leg).

Male. Length about 2.5 mm.; black, the legs and antennæ dark fuscous; cheeks black; wings perfectly hyaline, stigma fuscous, nervures light brownish.

In Burmese amber; received from Mr. R. C. J. Swinhoe.



EXPLANATION OF FIGURES

Fig. 1. *Protofoenus swinhoei* Ckll.
Fig. 2. *Hyptiogastrites electrinus* Ckll.
Fig. 3. *Sciara burmitina* Ckll.
Fig. 4. *Trichomyia swinhoei* Ckll.
Fig. 5. *Electrocyrtoma burmanica* Ckll.
Fig. 6. *Myodites burmiticus* Ckll.

DIPTERA.

Sciara burmitina n. sp. (Mycetophilidæ).

(Fig. 3, A, wing; B, palpus; C, leg; D, abdomen; E, end of antenna).

Male. Length 4.4 mm.; black, the legs brownish; palpi slender, last three joints subequal; antennæ thick, tapering and slender apically, the middle joints longer than broad, the apical ones slender, much as in *S. sendelina* Meunier; thorax very convex in lateral profile, the dorsulum forming half a circle; wings hyaline, apparently slightly dusky, with dark veins, subcosta entire; legs very long; femora thick; tibiæ very long and slender, with minute short hairs; hind coxæ longer than head; abdomen elongated.

The wings are crumpled, so that it is impossible to get exact measurements, and the figure given, though approximately correct, must be regarded as diagrammatic. The complete subcosta is an archaic character, and might suggest a distinct genus, but the living *S. lugens* Johannsen, as figured, is not very different.

In Burmese amber (Burmite); received from Mr. R. C. J. Swinhoe.

Trichomyia swinhoei n. sp. (Psychodidæ).

(Fig. 4, A, wing; B, head and thorax; C, end of abdomen).

Male. Length about 1600 microns, wing about 1410 microns long and 560 broad. Dark brown or black, the wings clear hyaline. Antennæ long and slender, apparently 16-jointed, the joints beyond the second long and slender, hairy; palpi of moderate length; legs slender; wings with marginal fringes, and long hairs on the veins, venation as shown in figure. The thorax, in lateral profile, is produced anteriorly above, angular; the scutellum is prominent. Unfortunately the anal field of the wings cannot be seen, but the insect certainly appears to belong to *Trichomyia*, not to *Sycorax*.

In Burmese amber, received from Mr. R. C. J. Swinhoe. It is in the same piece of amber as *Sciara burmitina*. The genus *Trichomyia* appears to be on the wane. Meunier describes no less than eight species from Baltic amber (Oligocene), but Brunetti does not report the genus at all in his account of the Psychodidæ of India. In North America we have only a single species listed in Aldrich's catalogue, and that is Mexican.

Anthomyia (s. lat.) **laminarum** n. sp. (Anthomyiidæ).

Female. Length 6 mm., thickset (form nearly as in *Spilogaster*), black; wings about 4 mm. long, broad, hyaline, costa with short black bristles, costal margin conspicuously elevated and convex before end of auxiliary vein; head shaped (in lateral profile) much as in Williston, N. Am. Diptera, 3rd edition, p. 335, fig. 27, the top of head broad, and with only very delicate bristles, though the front has conspicuous bristles; dorsum of thorax, anterior to wings, with no long bristles, but there are long bristles at level of wings, the whole arrangement here apparently as in *Lispa;* abdomen stout, bristly, with a distinct short ovipositor; the depth of abdomen (doubtless increased by pressure) is 2.3 mm. The venation is much as in Williston's figure of *Choristoma.* Auxiliary vein complete, but pale; first vein ending soon after auxiliary (a deceptive appearance of its continuing parallel with the margin is due to the lower edge of the thick costa); anterior cross-vein about middle of discal cell, being 1040 microns from apex and about 1024 from base; first posterior cell not contracted at apex; width (depth) of submarginal and first posterior cells at vertical level of end of second vein each about 432 microns; superior apical angle of discal cell practically a right angle; apex of third posterior cell (angle between fifth vein and lower margin of wing) very acute.

Wilson Ranch, Miocene shales of Florissant, Colorado (Wickham). Readily known from the two previously described Florissant Anthomyiids by the anterior cross-vein being practically at the middle of the discal cell. These fossils cannot be definitely referred to modern genera, many of the essential characters being invisible. There is no doubt that the present insect is generically distinct from the other two, as genera in this family are now understood.

Electrocyrtoma new genus (Empididæ).

Minute flies resembling the modern genus *Cyrtoma* Meigen, but the rather large antennæ have a long terminal bristle; hind tibiæ and basitarsi not at all thickened; abdomen short, not extending much beyond hind femora; no detached vein in middle of wing below fourth; a considerable interval between separation of third vein from second and anterior cross-vein. Thorax greatly elevated, finely hairy; scutellum prominent, hairy; humeral cross-vein straight (not oblique); discal cell entirely open, but a slight bend in fourth vein at a point where apex of cell probably existed in an ancestor; end of anal cell and of second basal nearly in the same line; legs long and slender, but anterior femora thickened basally, the base about twice as broad as the apex.

Electrocyrtoma burmanica n. sp.

(Fig. 5, wing, antenna and dorsal profile of head and thorax).

Male. Black, with perfectly clear wings; length about 1280 microns. The following measurements are in microns: length of antennæ, 256; width of anterior femora near base, 80; length of anterior tibiæ, 352; length of abdomen (approx.) 640; length of hind femora, 464; of hind tibiæ, 416; of hind basitarsi, 208; of wing (approx.), 1040.

In Burmese amber, received from Mr. R. C. J. Swinhoe.

The loss of the outer side of the discal cell in the Empididæ appears to be a specialization. It is surprising to find in Burmese amber, the fauna of which seems on the whole to possess rather primitive characters, an insect more specialized than the ordinary Empididæ of modern times.

There is no affinity with any of the species described from Baltic amber.

COLEOPTERA.

Myodites burmiticus n. sp. (Rhipiphoridæ). (Fig. 6).

Length about 3.5 mm.; head, antennæ, prothorax and elytra black, but thorax behind level of elytra and dorsum of abdomen (except toward apex) pallid, probably ferruginous; antennæ flabellate, with at least five or six long processes; elytra short, scarcely reaching beyond base of abdomen; wings ample, hyaline, the costa pale ferruginous; legs slender, ordinary.

In Burmese amber (Burmite), received from Mr. R. C. J. Swinhoe.

I cannot distinguish this from the modern genus *Myodites*, but it is so placed in the amber that it is impossible to get a good view of the details of structure under the microscope. A species of *Myodites* has been recorded from the Oligocene of Rott, in Germany. The fossil seems to belong to *Myodites* rather than to *Emenadia*, which occurs today in the India region.