nephrectomized mice. Unfortunately we have been unable to keep bilaterally nephrectomized mice alive long enough to perform a positive experiment.

Our data are in agreement with Rein's (*7, 8*) hypothesis of "hypoxilienine," the spleen factor which is stored in the liver, and with the suggestion that hypoxilienine acts as an erythropoietic factor.

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10 November 1964

Flora and Fauna on Backs of Large Papuan Moss-Forest Weevils

Abstract. *Large, living, flightless weevils feeding on leaves of woody plants in high moss forest on various New Guinea mountain ranges have plant growth on their backs. Fungi and algae have been found on 11 species of* Gymnopholus, *lichens on six species, and liverworts on one species. In other genera of weevils, on the same mountains, there are additional specific associations with fungi, algae, lichens, and liverworts. The fungi and lichens, at least, are inhabited by oribatid mites of a new family, which may spread the plants from beetle to beetle. Also, nematodes, rotifers, psocids, and diatoms occur among the plants. Specialized scales or hairs, and a secretion, in depressions on the weevils' backs, appear to be associated with encouragement of the plant growth. Mutualistic symbiotic relationships seem to be clearly indicated.*

In high-altitude moss forests in New Guinea, a symbiotic relationship exists whereby cryptogamic plants (fungi, algae, lichens, liverworts) of a number of species of 12 or more families grow on the backs of large weevils. The plants represent groups normally living on bark and leaves, as far as is known, and the weevils feed on leaves of woody plants in the very damp environment. Shade and humidity requirements of the plants are fairly high, and in this environment rain and fog are very common. Temperatures are normally between 12° and 33°C. The weevils represent a number of species of two subfamilies and are large, heavily sclerotized, flightless, more or less slow-moving, and evidently long-lived. Some of the plant growth appears to have required 3 to 5 years to develop, and this with other factors speaks against a parasitic association. Furthermore, the weevils seem to be specially adapted, by modification over a long evolutionary period, to encourage the plant growth, which may serve the function of protective camouflage for the weevils. The natural enemies of the weevils are not yet known, but may include birds of paradise.

Living in the plants on the weevils are oribatid mites, representing a new family, and nematode worms, rotifers and diatoms, not yet studied. Also there is evidence that psocopterans feed on some of the plants on the beetles. The mites may aid in transfer of the plant spores from weevil to weevil. A secretion, and modified scales and hairs, on the weevils, seem to assist the plant growth in making a start. The newly emerged weevils have the structural modifications (depressions, tubercles, scales, hairs), and the secretion, to encourage the plants, but do not have plant growth initially. The activities of the weevils appear to give minimum disturbance to the plants. Although the animals living with the plants are fairly numerous, their moving environment may be a little less favorable than in the plants on the normal substrates, so that this may benefit the plants, as may some measure of similar protection from other enemies or competitors. Of course the mite may be a symbiote in the sense of serving to transfer the plants to new beetles, at least. The nematodes and rotifers may not directly damage the plants, but may feed upon microorganisms and waste products within the association.

The genus *Gymnopholus* (Curculionidae: Leptopiinae) includes over 40 species (*1*) of large weevils, restricted to the mountains of New Guinea. They have been found in various mountain ranges, almost entirely in eastern New Guinea. The species vary in length from about 20 to 40 mm, and some are quite broad. Those species in the lower mountains are mostly smooth and glabrous, generally black, but sometimes with patches of metallic scales. Only the high-altitude species, and some of the mid-altitude species which live mostly in moss forest and in the border area of the alpine grass zone and alpine shrubberies, have rough or sculptured upper surfaces with special modifications which seem to be correlated with the growth of plants on their backs. These areas on the pronota and elytra, inaccessible to the legs of the beetles, include large depressed areas, series of pits, or depressions between vermiculate or reticulate ridges. Furthermore, there is generally a pair of high tubercles on the pronotum and one or two on the posterior part of each elytron, which further protect the plant growth. A thick waxy secretion which appears to foster the growth of plants on the protected areas is apparently produced by glands in the areas of the depressions. Some of the weevils have the depressed areas lined

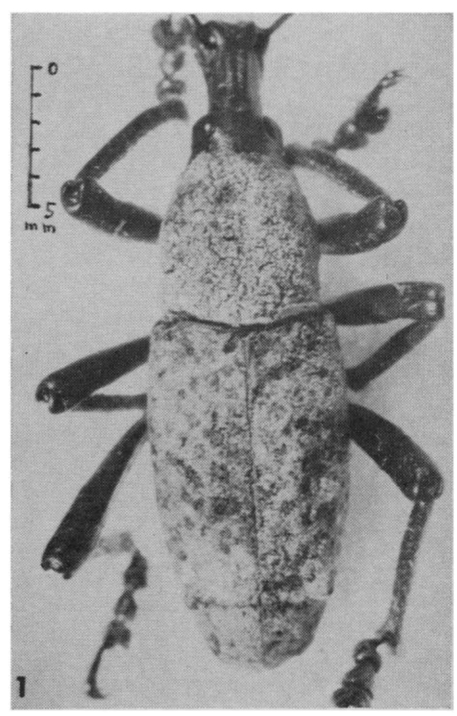


Fig. 1. *Gymnopholus* sp. from Mt. Kaindi, North-East New Guinea, 2300 m., with pronotum and elytra covered with fungal growth; darker spots are deeper pits, possibly with higher concentration of algal growth; shiny dots in these are oribatid mites (× 4).

Fig. 2. *Gymnopholus* sp., same locality, with elytra covered with growth of lichen, *Parmelia* (*Parmelia*) *reticulata* Taylor; some oribatid mites in depression at center of pronotum and in clefts in lichen (× 4).

with peculiar convex metallic green scales bearing, or terminating with, fine erect hairs. Others bear complex rosette-like compound scales with a short stout seta in center, resembling a blossom. Other weevil species have large hairs or bristles on the edges of the depressions, which appear to help protect the plants. Some of the hairs are specially modified, quite stout and with short branches.

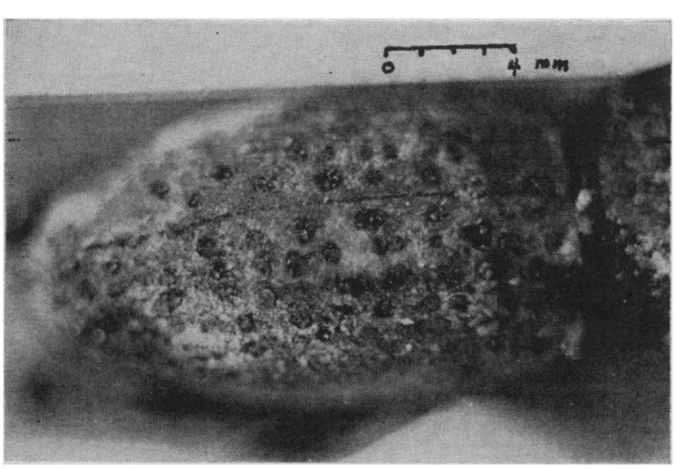
At least 11 species of the *Gymnopholus weevils* [*G. reticulatus* Marshall, *G. cheesmanae* Marshall (*2*), and nine new species (*1*) living at an altitude of 2000 to 3500 m in the Bismarck, Owen Stanley, Finisterre, and associated ranges] bear extensive growth of fungi in the protected depressed areas out of reach of the appendages (Fig. 1). The fungal growth is in some cases up to 1 mm in thickness and is in part mixed with algal growth. The fungal growth is in more or less of a continuous layer, or it occurs in the depressions or grooves. It forms a somewhat solid mass, generally whitish, with occasional fruiting bodies of red, orange-buff, or black showing on the surface. In many of the specimens the solid layer has cracked after or during drying, like a layer of dried mud. Over 250 specimens have been found infected with fungi, and these comprise most of our specimens. Groups of fungi represented include Fungi Imperfecti (?Leptostromataceae, ?Nectrioidaceae), Ascomycetes (Helotiaceae, ?Micropeltaceae), numbering at least five species (*3*).

Blue-green algae of a number of types occur mixed with the fungi, as well as some other types of algae, possibly including Trentepohliaceae (*4*).

Lichen growth has been found on six of the same species of weevils, and on individuals supporting fungal and algal growth. The lichens are more limited in occurrence, with obvious growth noticed on only about 20 beetles, although more have incipient growth. The lichen growth occurs on the pronotum or on the elytra, and it appears to get its start on already existing fungal growth. The greatest area covered, among the specimens observed, is almost the entire area of the elytra (Fig. 2). This growth appears to be from 3 to 5 years old. Vegetative reproduction is evident in these samples. At least six species of lichens are involved: a *?Physcia*, four species of *Parmelia* [including *P. (P.) reticulata* Taylor and *P. (P.: Hypotrachyna) crenata* Kurok.], and an *Anaptychia* (*5*).

One weevil species has an apparently uniform, white, waxy layer on exposed surfaces, with setae on sides of depressions and flat grooves on the bottoms of the pits. It is less affected by plant growth, but supports liverworts.

Living on and within the extensive fungal growth, and under lichens, on many of the weevils is a species of apparently fungivorous (perhaps also algophagous and lichenivorous) oribatid mite (Fig. 3), representing a new family (*6*). Adults measure about 0.2 mm in length. As many as 60 of these mites may be seen on the back of one weevil, without digging into the fungal or lichen growth. The mites mostly occur in small cells they have formed, perhaps from feeding in depressions. Some are on the surface, some slightly imbedded, and others are beneath the surface of the fungi. Some congregate in pits. All stages of the mite are found together. In some of the newly emerged beetles, still lacking fungal growth, an occasional mite is found in one of the deeper elytral depressions. This seems to suggest strongly that the mites transfer the plant spores to the new beetles to start the fungus gardens. However, air-borne spores may adhere to the sticky secretion. The mites, in the various plants on the different *Gymnopholus* weevils, seem to represent but one species. Oribatid mites are not normally found on beetles, being characteristic of leaf litter, the bryosystem, and similar environments. On another



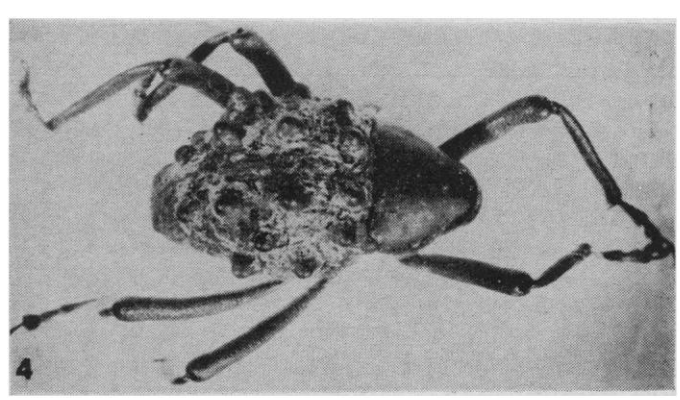


Fig. 3 (left). *Gymnopholus* sp., Bulldog Road, North-East New Guinea, 2850 m altitude, showing depressions in elytra harboring oribatid mites (shiny dots) among fungal or algal growth (× 4.5). Fig. 4 (right). Cryptorrhynchine weevil with liverworts growing between high tubercles on elytra; Mt. Kaindi, 2300 m (× 4.5).

type of weevil, many mites of another group seem attracted to a quite different type of fungus.

Also occurring in the plant growth on the weevils' backs are nematodes and rotifers. A diatom was also found and undoubtedly other microscopic plants and animals occur in the plant growth. That some of the same weevils bear dead psocopterans in fair numbers, as well as their exuviae, suggests that these insects may have been feeding on the plant growth, probably on algae and fungi.

These weevils feed on the leaves of woody plants. They are most likely polyphagous. A mid-montane smooth species, *Gymnopholus weiskei* Heller, feeds on *Melia azedarach, Trema amboinensis, Pipturus argenteus,* and *Tephrosia candida*, representing four plant families. Another feeds on *Nothofagus*; another on *Laportea.* One of the new symbiotic species, defoliating *Rhododendron commonae* at 3500 m on Mt. Strong (*7*), bears extensive fungal and lichen growth.

Only a few of the female weevils show evidence of rubbing off of plants by action of males in mating. Perhaps the rubbing of the dorsal surface is largely confined to the posterior end of the sutural ridge and the apices of the posterior elytral tubercles, which rarely support plant growth.

Several genera of the weevil subfamily Cryptorrhynchinae in the same moss-forest environments also bear plant growth, predominantly of fungi and algae. One (Fig. 4) bears extensive growth of liverworts (Metzgeri-ineae: *Metzgeria*; and Lejeuniaceae) (*4*), and one bears a lichen. These weevils have prominent tubercles or ridges which obviously protect the plant growth from being rubbed off.

All of these weevils are flightless. The wings of the species examined are vestigial in various degrees. The elytra are generally more or less strongly fused.

Some long-legged parasitic mites are fairly common on these weevils, generally on the ventral surfaces, although one of the smooth, nonsymbiotic species, *Gymnopholus gressitti* Marshall (*2*), sometimes has a mite attached immediately behind the large tubercle on each elytron.

This report may represent the first record of lichens and liverworts on insects and of algae on terrestrial insects (*8*). Hendrickson and Weber (*9*) reported lichens on Galápagos tortoises as the probable first record of lichens growing on living animals. Algal growth on the sloth is well known. Few records exist of nonpathogenic fungi other than Laboulbeniales growing on living insects (*10*), particularly on insects other than termites and ants (*11*).

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12. Supported by NSF grants (GB-518,3245) to Bishop Museum. Specimens were collected by W. W. Brandt, C. D. Michener, and ourselves. A few were taken earlier by Miss Evelyn Cheesman. She and the late Sir Guy Marshall, who studied her material and some of the early Gressitt and Szent-Ivany specimens (*2*), did not recognize the plant growth; nor did we until Sedlacek began to find individuals with conspicuous lichen growth. We thank R. K. Benjamin, S. Carlquist, G. W. Gillett, M. Hale, J. Proskauer, A. C. Smith, H. St. John, W. A. Weber, and J. Womersley for advice. Mites were mounted and sent to J. Aoki by W. J. Voss.

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Rabbit: Frequency of Suckling in the Pup

Abstract. *Rabbit does were given free access to their young, access once a day, and access twice a day. In all three groups the young were nursed only once every 24 hours. Growth curves for the pups from day 2 of age to day 30 were identical for all three groups. The restriction of suckling to once a day appears to depend on the mother and not the pups.*

Several aspects of maternal behavior in the rabbit have been described and subjected to experimental analysis (*1*). However, one characteristic which has not been systematically investigated is the frequency with which the mother nurses her young. Although reports in the naturalistic literature suggest that hares and rabbits may only nurse their young once a day (*2, 3*), this observation does not appear to be well known, and it has not been experimentally verified. The observation, however, is consistent with the findings of Cross and Harris (*4*), who removed the does from their week-old litters and periodically placed them with their young during the day. The doe nursed the pups only once a day, though the pups attempted to suckle more frequently.

Because of its unusual nature, we have attempted to examine this behavior in detail and to obtain both quantitative and observational data on suckling in rabbit pups from the day of birth. Quantitative data were the body weight curves of the young from day 2 of age to weaning, and observational data were obtained by close inspection of the mother and young throughout the day. We established three groups in which the doe was given (i) free access to the young, (ii) access once a day, or (iii) access twice a day. The individual pups of each litter were weighed daily from day 2 through day 16 and on days 19, 22, 26, and 30. The litters were all reduced to 4 to 6 in number. There were three litters in the "free-access" group, five in the "once-a-day" group, and four in the "twice-a-day" group. Dutch-belted rabbits were used.

Our general observations indicate that the doe nursed the young only once each day under both conditions in which the mother had access to the young more than once a day. In fact, during the second exposure under the twice-a-day condition the doe rarely entered the nest box containing the young or, if she did enter, she would leave immediately; hence she could not have nursed or contacted the young to any significant degree.

All the females in the twice-a-day group nursed in the morning and not in the evening. From the state of the young in the free-access situation (distended stomachs, often wet) it was presumed that these does also nursed early in the morning—that is, before the period when the young were weighed (8 to 10 a.m.).

Between 13 and 16 days of age