The Ecology of the High Himalayas

Around 15,000 feet the slopes below Mount Everest support a typical alpine community of plants and animals. Above this altitude there is a unique community that is founded on wind-blown organic matter

by Lawrence W. Swan

The several parties of adventurous climbers who have stood on the summit of Mount Everest during the past decade have not tarried there long enough to find out whether or not the top of the earth harbors any permanent inhabitants. It may be that the upper limit of the settled community of life lies somewhere below on the flanks of the mountain. Little is known about the ecology of the high Himalayas under the lofty peaks of Everest, Kanchenjunga, Makalu and Cho Oyu. This area, embracing some 2,000 square miles of wilderness high above the tree line, is without vehicles or laboratories. The investigator is only as good as his lungs, legs and endurance; he must walk and climb for a month to acclimatize himself, and even then, in the thin air among the barren rocks, he finds it difficult to shake the impression that he is only one step from the moon.

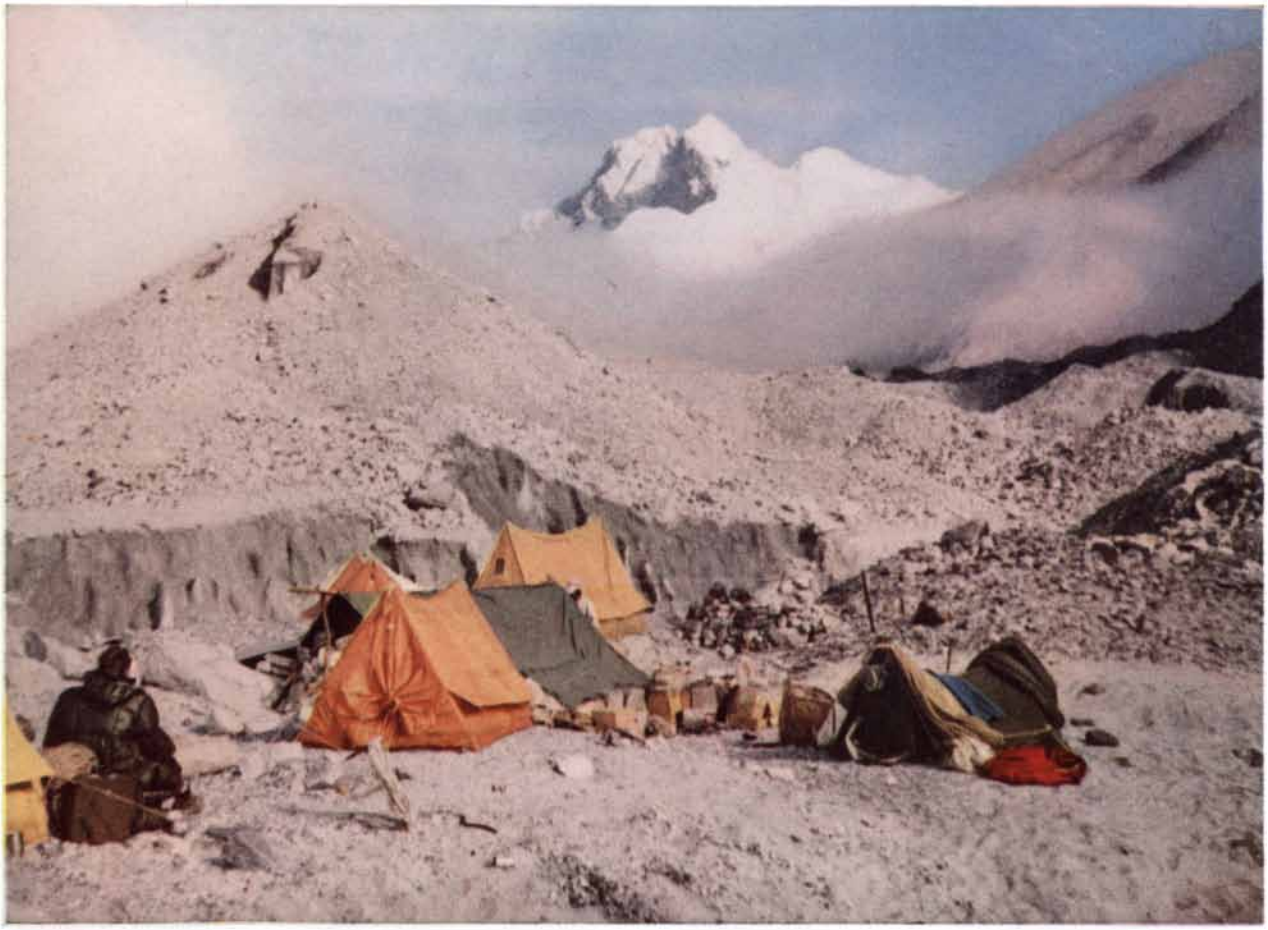
Lack of air sets the primary ceiling on the altitude to which a man may climb and function. But the black, yellow-billed birds called choughs (*Pyrrhocorax graculus*) visited the high camps of early Everest expeditions at nearly 27,000 feet, and last year the Indian expedition to Everest found the frozen carcass of an eagle at over 25,000 feet. The British explorer George Lowe, who has spent as much time as anyone at mountain altitudes above 23,000 feet, has told me of watching from the slopes of Everest while a flock of bar-headed geese (*Eulabeia indica*) flew in echelon directly over the summit. On an April night from a camp at 15,000 feet on Barun Glacier, I myself have heard the distant honking of these birds flying miles above me unseen against the stars over Makalu, on their way to the lakes of Tibet. It is known that the bar-headed geese start from the lakes of India at sea level and complete their spring migration in a single majestic flight; one can only speculate on what adaptations permit them to accomplish this feat. All of these birds, however, must be reckoned along with men as no more than occasional and transient visitors to the high places of the Himalayas.

The first creature credited as a permanent resident of the extreme heights of these mountains was a species of jumping spider (family Salticidae). Several immature specimens were collected at 22,000 feet on Mount Everest by members of a British expedition in 1924. For many years this find was a subject of controversy. Small spiders can be carried great distances by their air-borne threads, and it was argued by some that the Everest spiders had been carried up the side of the mountain by the wind. Those who insisted that the spiders had been collected from their native habitat had to solve a problem of logic. Spiders are universally predaceous; it was necessary to show that there were insects as well as spiders at 22,000 feet. Furthermore, there would have to be plant food for the insects. The collectors had seen neither plants nor insects, only rock and ice. One partisan advanced the self-defeating notion that the spiders ate other spiders. Spiders do eat other spiders, but this would scarcely provide the basis for a permanent population, at any altitude.

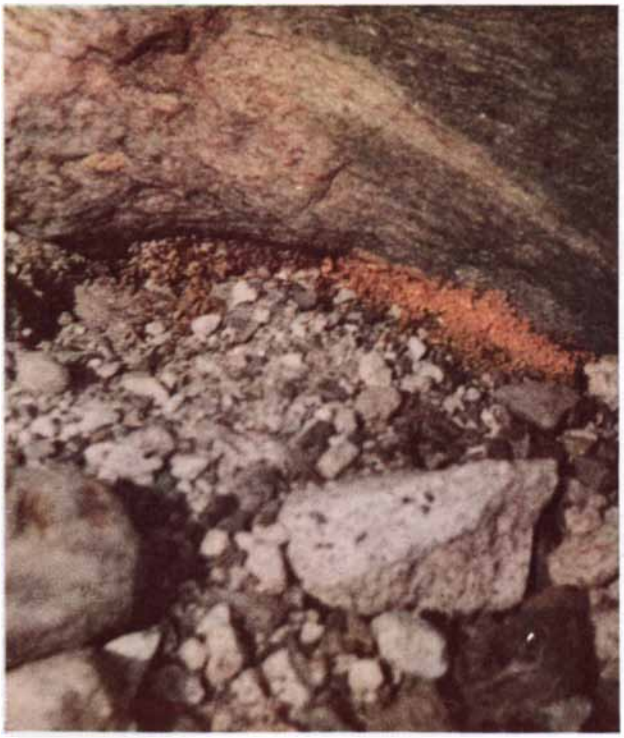
As a student of the ecology of the alpine regions of North America, I had my first opportunity to look into the enigma of the jumping spiders of Mount Everest in 1954 when I accompanied the American Himalayan Expedition to Makalu. (Last year I made a second trip to the region, on an expedition led by Sir Edmund Hillary and sponsored by the World Book Encyclopedia.) At first it seemed that these spiders were truly a wind-blown myth. There were no jumping spiders of any species seen during my first month of acclimatization on the lower slopes of the mountain.

Spiders of many other kinds, however, were observed occupying easily understandable environmental niches. Below the tree line, at 13,500 feet, in the sheltering fir and rhododendron forests, there were orb-weaving spiders. For some distance above the tree line the irregular webs of theridiid spiders were common, but these disappeared with the shrubs. In the higher regions I collected grass spiders of the family Agelenidae. Still higher there were ground-hunting wolf spiders of the family Lycosidae, but these became scattered and infrequent in the rock-strewn slopes at 17,000 feet. Above this level there were some plants and hidden insects, but spiders—even wind-blown spiders—were not to be seen. At higher levels the south-facing slopes of the range were sheathed in massive ice.

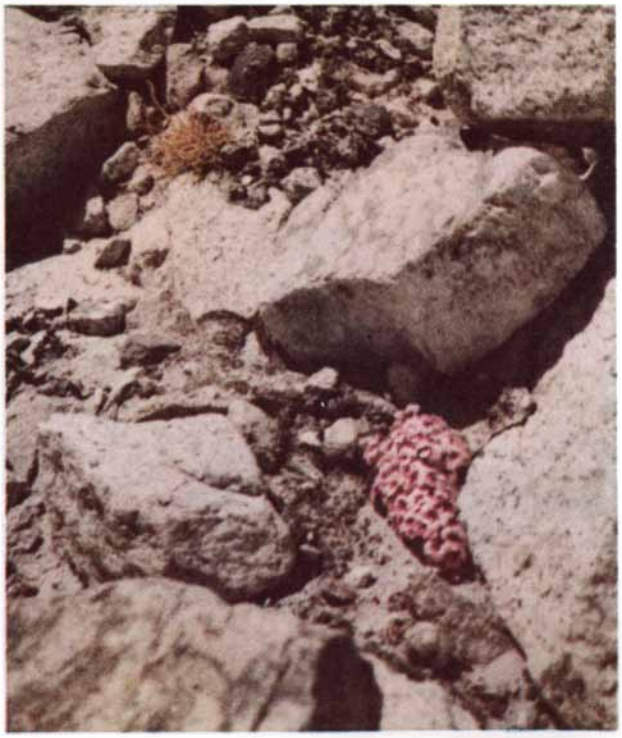
The alpine zone of the Himalayas, above the tree line and below the upper limit of green plants, supports the complete sort of biological community that is observed in other comparable regions of the world. The heights to which it reaches are a function, from place to place, of local conditions, determined especially by the altitude of the snow line, the character of the soil, the availability of water in the liquid state and the exposure of the mountain slope to sunlight. Up to 17,000 feet there is still what can be called a plant cover, dominated by dwarf rhododendron (*Rhododendron setosum* and *R. anthopogon*) and juniper (*Juniperus squamata*) and including various grasses, sedges, buckwheats, gentians and small primulas, plus the sandwort (*Arenaria*), edelweiss (*Leontopodium*), rock jasmines, (*Andro-*



CAMP IN THE HIMALAYAS was pitched at 18,000 feet on Barun Glacier during 1954 American Himalayan Expedition. The highest white peak in background is Lhotse; next highest to right is Everest. Photographs on this and following page were made by the author.



HIGHEST KNOWN PLANT, a cushion plant (*Stellaria decumbens*), was found at 20,130 feet on the northern slope of Makalu.



PINKS (*Parrya lanuginosa*), named for their color, were found at 18,500 feet on Makalu. At upper left is a small brown sedge.

PATCH OF PLANT LIFE growing on a "shelf" of a slope appears as a dark oval at right in this photograph taken at 19,300 feet. The view is down the slope. The shelf is an area of water drainage. The snow seen farther down the slope is part of Barun Glacier.

BARREN ARID ZONE below a snowcap is seen from 20,000 feet. The barrenness of the area indicates that the snowcap does not give rise to surface water or streams. Although no plants were found, there were springtails (small wingless insects) under the rocks.

sace), sagebrush (*Artemisia*) and joint pines (*Ephedra*).

Insects are common in this region up to 16,000 feet. At these altitudes I have collected ants, bees, wasps, flies, butterflies, moths, beetles, true bugs, aphids, leaf hoppers, stone flies, May flies, thrips and grasshoppers. The behavior pattern of many of the insects illustrates a special feature of the environment at high altitudes: the sudden and extreme temperature changes that produce a variety of microclimates, which change from hour to hour in the course of a day. Flying insects disappear at night into crevices and holes. When the sun is shining, they are remarkably active; in cloudy weather they behave erratically. It is a common sight to see bumblebees and flies running on the ground or actually lying torpid beside a rock. More striking is the behavior of some butterflies: they not only come to earth during cloudy weather but lie on their sides in a manner most unbecoming to butterflies.

The common ground-hunting wolf spiders appear to be more resistant to cold than their insect prey. I have seen them active in the open when the snow was falling. They were carrying captured insects. To all appearances they had taken advantage of the sunless hours to seize ordinarily more active prey in the state of numbness and torpidity brought on by the cold. These observations are explained by the temperature curves that determine the changing microclimates [*see illustration on page* 73]. In the late afternoon, when the sun has sunk below the surrounding mountains, the warmest available environment is the surface of the ground. It is at this time, when flying insects are seeking night shelter, that the ground spiders go abroad.

The temperature of melting snow hovers around 32 degrees Fahrenheit in sun or shade. I have seen daddy longlegs (phalangids) running on snow in the sun; their activity showed that their body temperature was much higher. I found one phalangid that had somehow been trapped in the snow. The heat of its black body had melted the snow and the helpless creature, in spite of its long legs, had slowly descended into a self-made hole, where it had frozen. In the sunlight on snow a black phalangid may have a body temperature approaching 90 degrees F.; fortunately its long legs keep its body away from the snow. A black insect on the snow, unless it could live on the film of melting surface water, may well be doomed to sink into the snow.

At night a black-bulb thermometer exposed to the sky records a lower tem-

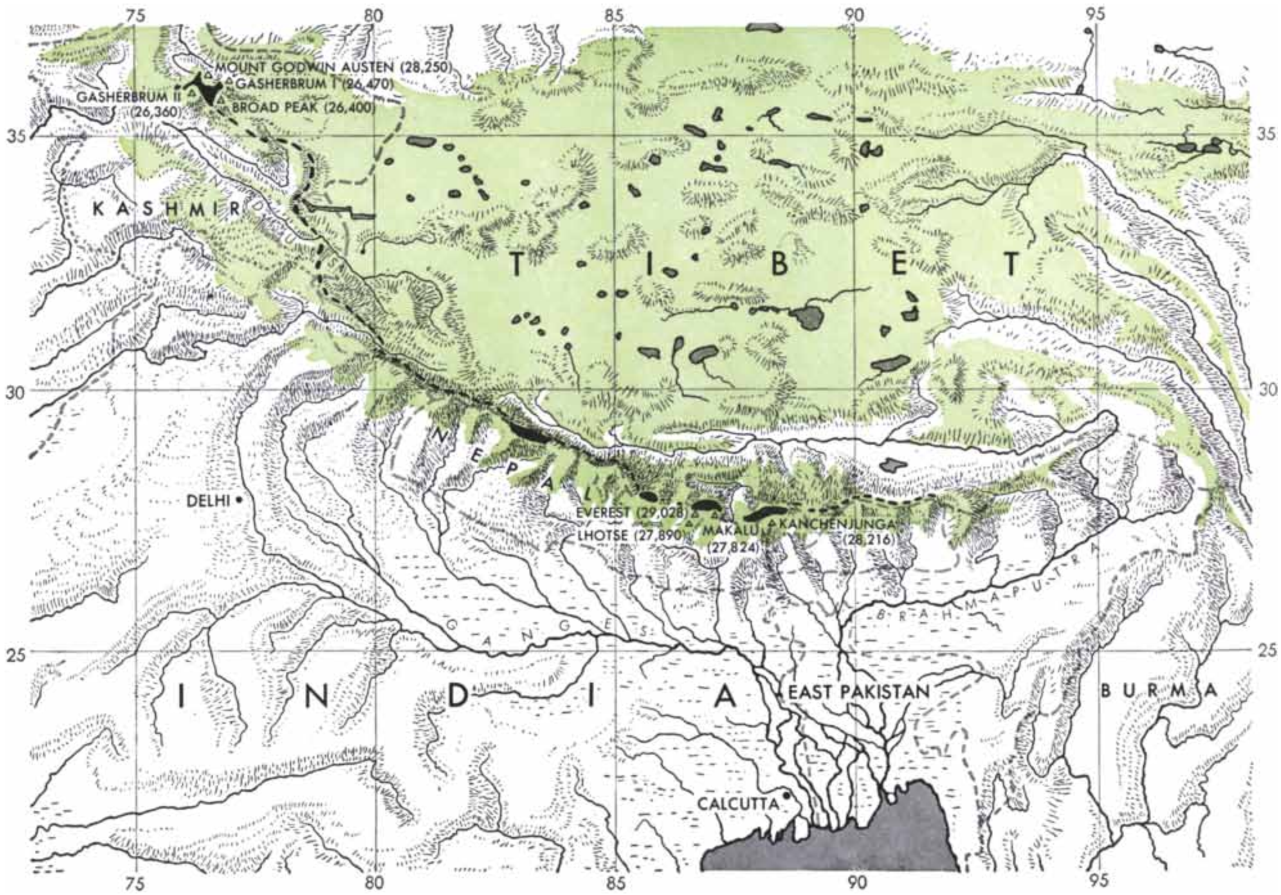
SUMMIT OF EVEREST (*center*) is seen from southwest in this aerial photograph. Rock near summit is exposed and wide snowless areas on mountains to the north extend up to 22,000 feet.

perature than a sheltered instrument. This is a measure of the intense reradiation of heat to the night sky. Hence the environment of nocturnal animals is very cold. Mammals such as mice, foxes and snow leopards find their lairs or shelters below ground, where the daily temperature variation (as indicated by the curve for ground temperature at a depth of six inches) is much narrower. This is the warmest available secluded environment; if the nocturnal mammals slept in the sun, they could well be too warm. On the same mountainsides, therefore, insects live in a tropical environment side by side with mammals that lead their active lives in an arctic world of subfreezing temperatures. These are the extremes, and the habits of other animals fall between them. Individual differences in behavior and ability to move from one place to another thus provide opportunity for members of the alpine community to find a wide variety of environments.

Since most reports of the Himalayan snow line refer to an elevation of about 17,000 feet, it may not be apparent how life can extend upward to more than 20,000 feet. The southern faces of the eastern Himalayas are exposed to a snowy deluge between June and September, and the snow on the outlying peaks may accumulate at 15,000 to 16,000 feet. Deeper in the range—toward Tibet—the precipitation drops off rapidly. Beyond the highest crest, in Tibet itself, it may decline to less than 15 inches. The northern gradient of the lighter snowfall gradually lifts the altitude of the snow line. In the innermost Himalayas, where there is less cloudiness and correspondingly a greater intensity of sunlight, the very term "snow line" becomes inappropriate. Tongues of snow descend to 18,000 feet, but vast areas are snowless with rocky extensions rising to great altitudes. If there is a continuous slope, and if the mountain mass is sufficiently large, the snowless rock may reach to 23,000 feet.

Near the end of May in 1954 our explorations led us up the glaciers toward the northern slopes of Makalu. Here, near the crest of the Himalayas, where the heaplike ridges of Tibet stand in sharp contrast to the more heavily snowed slopes to the south, the environment changed abruptly. At the upper limits of the alpine zone there were large regions bare of snow. And we could see, on the northern shoulders of Mount Everest, the same rock and snow buttresses where the jumping spiders had been collected 30 years before. In this setting, at 18,000 feet on the bare rocks beside the glacier, my eye was caught by the unmistakable bouncing and hesitating movements of a small black salticid spider. From this point to above 20,000 feet they were the only spiders collected. They were indeed permanent residents of a most unusual and desolate region.

After some study it became apparent that the spiders had available as prey a sparse population of anthomyiids: little flies that resemble the common housefly. These they stalked in the sun. When the sun was obscured by clouds, the spiders retreated under the rocks. Here they preyed on springtails: crawling and jumping insects of the order Collembola. Anthomyiid flies and springtails are for

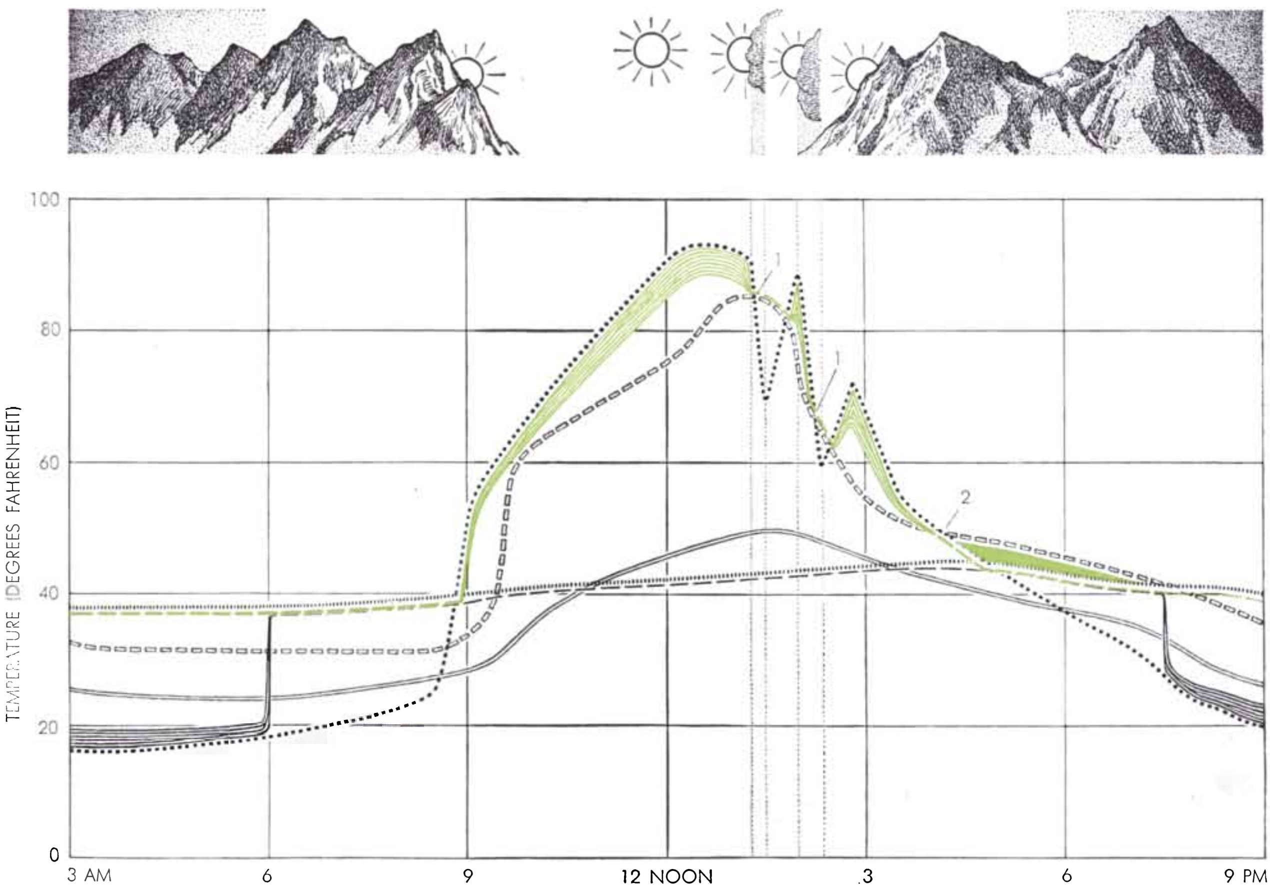


LIFE AT EXTREME ALTITUDES of 19,000 to 22,000 feet in the Himalayas is represented on this map by a group of small black areas. The gray areas are lakes. The land area above 13,000 feet is in color. The numbers in parentheses indicate altitude in feet.

the most part fungus-eaters or live on rotting vegetation. Plants and the fungi that promote their decay, although scarce and scattered, still persist at these altitudes.

In addition to the anthomyiid flies and springtails, the salticid spider may have another prey; the pupal case of a fly found on one occasion under a rock carried the neat round emergence hole of an unknown insect parasite. The salticid, in any event, is the primary predator of this supremely simple food chain. Herbivorous and predaceous mites, together with small centipedes, may range above 19,500 feet, but they were not collected above 19,300 feet. Once I found the nest and eggs of a snow partridge at nearly 19,000 feet; this bird feeds on roots and leaves far above that elevation. All other animals observed at these altitudes appeared to be transients. Among them are scavengers such as choughs, lammergeiers (*Gyptaëtus barbatus*) and Himalayan griffon vultures (*Gyps himalayensis*) that follow man and his domestic animals wherever they go. Domesticated yaks and sheep will wander wherever plants are available, and the same is true for wild sheep such as the bharal (*Pseudois nahura*). These animals are preyed on by snow leopards, which together with wolves and foxes may pursue them in their wanderings to very high altitudes. The small Tibetan weasel (*Mustela altaica*), which seeks out the eggs of snow partridges, is capable of raiding over wide areas wherever snow partridges are found. Mice of various kinds and small mouse hares, or pikas (*Ochotona ladacensis*), have been recorded at 19,500 feet, but they are more characteristic of the lower-altitude communities, where they provide a basic food for predators.

At about 20,000 feet the community of life thins out drastically. Plants become restricted to two general types of niche. They congregate where there is some subsurface drainage of water from a higher snow field, and they grow around the base of rocks. Plants such as the sandwort, edelweiss, the fluffy *Saussurea* and gentian, which are more general at 16,000 feet, appear to grow



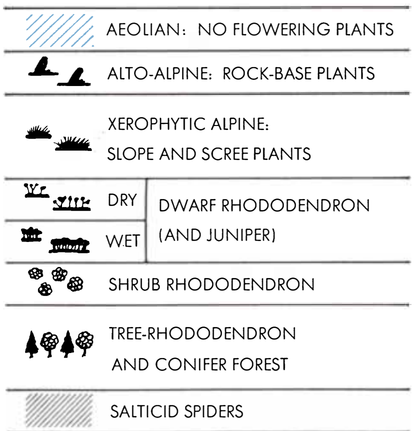
ACTIVITY OF INSECTS AND MAMMALS at 16,000 feet on Ripimu Glacier in eastern Nepal was recorded by the author on October 10, 1960. The "Exposed-black-bulb temperature" is most representative of the environmental temperature of insects.

MAKALU AND VICINITY were visited by the 1954 American Himalayan Expedition, in which the author participated. The map, keyed to legend at right, shows the distribution of plant life in the region around Makalu and the location of the salticid spiders found by the author, as well as the route of the expedition (*colored broken lines*) and its camps (*roman numerals*). Numbers indicate altitude only in the rock-base niche at these higher elevations. The grasses and sedges, which are hardier, become circumscribed to the same niche but at correspondingly higher elevations. At 20,130 feet I found a small cushion plant (*Stellaria decumbens*) and in this area no evidence of other plants. It seemed that this was near the upper limit for flowering plants; in all likelihood 20,130 feet stands as the highest altitude at which any living plant has been collected. There were, however, many additional slopes I did not succeed in exploring; it is reasonable to expect that flowering plants can be found still higher.

Lichens, so often considered a characteristic feature of high altitudes, are scarce, small and often dead at elevations of above 18,000 feet in the Himalayas. These plants are dependent on surface water, and their miniature size and infrequency point clearly to the dessicated state of the environment. Water as a liquid is largely confined to the subsurface and, except for glacial pools or snow fields covering an impervious base, is rarely seen. In addition, the extremely small quantities of water vapor in the air may preclude the formation of dew. On the dry, rocky slopes the availability of water is perhaps the major limiting factor for life. The concentration of plants in wetter spots below the drainage points of snow fields brings the lichens once more into evidence. But the lichens do not appear here in their usual role as pioneers on rocks; they occur rather as secondary growths, entangled in the spongy heads of prostrate rooted plants. Their position and form are mute testimony to the presence of subsurface water.

A small patch of yellow or pink flowers on a barren, rock-strewn slope calls attention dramatically to the rock-base niche. It is obviously a favored locality, but it has been somewhat neglected in ecological studies. Whereas this niche may be a conventional matter at lower elevations and in the family garden, at high altitudes it is something special. Some of these unusual qualities become evident after a snowfall. Rocks tend to protrude from the snow and, in contrast with the snow, which reflects the light, the bare rock surface absorbs radiant energy from the sun. Snow in the sun at high altitudes sublimates into vapor rather rapidly and melting is diminished. Next to the rock, however, the temperature increase is such that the snow melts rapidly and the water seeps under the rock, where its evaporation is slowed.

In addition to these manifest advantages, the rock-base niche possesses a more subtle attribute. The lee side of the rock is an efficient trap for wind-blown debris. Dead insects blown high onto snow fields indicate clearly that winds transport larger materials, but the most significant debris is pollen. Juniper bushes produce huge quantities of pollen, and tents pitched some distance away from these shrubs may acquire a yellowish cast. In addition, the many high-altitude flowers seem to carry more pollen than equivalent species at lower altitudes, and the relatively large number of pollinating insects emphasizes this apparent abundance.



in feet. The aeolian zone, which is discussed in the text, is a new life zone containing insects and other organisms but no plants.

I was not able to verify the actual trapping of wind-blown pollen by rocks. But the quantities of dust and soil filling the spaces beneath tilted rocks seemed to suggest that pollen could not avoid being captured by the reverse wind currents on the lee side of obstacles. The most convincing evidence was a collection of fluffy seeds under a rock situated far beyond the highest level of growth for the plant. It seems that much more organic debris is blown onto a mountain than off it. The rough slopes transform the whole range into a sort of immense debris separator.

Springtails generally turned up under rocks wherever there were plants or some indication of plant remains. Yet under rocks on totally barren slopes at nearly 20,000 feet, on which there was no visible indication of plants, past or present, some springtails could still be found. In such a location the presence of these tiny insects clearly suggests that they subsist on wind-blown organic debris. If so, they must surely be present at still higher altitudes, far above the level at which flowering plants can survive. Thus in the fastness of the Himalayas, beyond the true alpine zone that is delimited by the presence of green plants, there is a new ecological system to be explored: the supra-alpine or aeolian community, sustained by wind-blown debris.

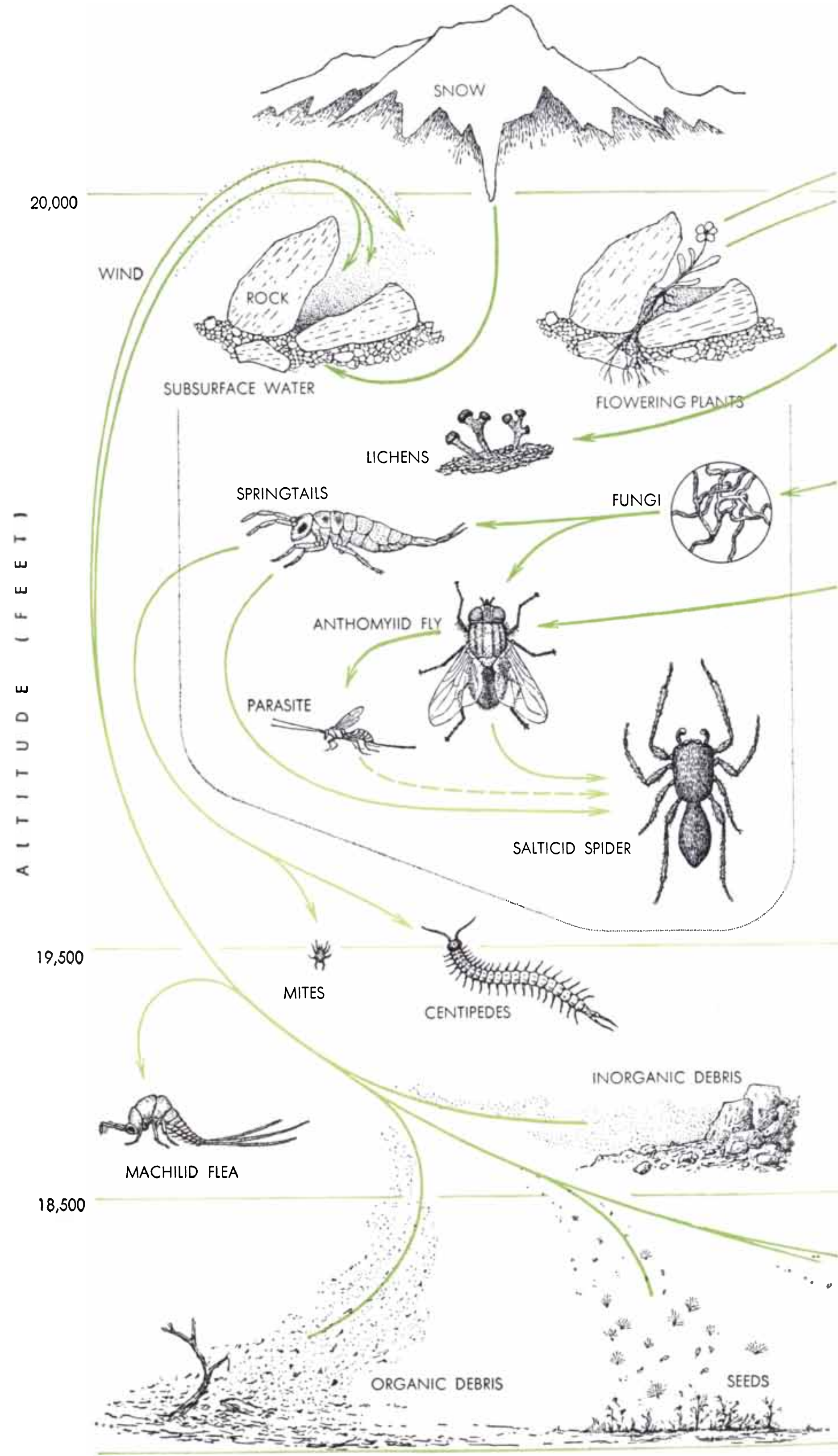
The springtails and the salticids and whatever other creatures share this realm with them would require some moisture and therefore periods of time when the rock-base niche experiences temperatures above freezing, but a consistent and prolonged growing season would not be necessary. Surprisingly, the maximum temperature recorded on a sunny day may be higher at higher altitudes. At 18,000 feet I have recorded 92 degrees F. on the rock surface and 60 degrees F. at a six-inch depth in sandy soil. The air temperature in the shade was 55 degrees F. All these temperatures were higher than equivalent recordings at 16,000 feet. With increasing altitude there is less atmospheric absorption of transmitted radiant energy, and in general at these highest altitudes there is less effective cloudiness. Furthermore, since the higher slopes and ridges are less frequently in the shade of still higher ridges, in good weather they receive more intense sunlight for longer periods. It may be less obvious why the high peaks also become so cold. The answer is that, with decreased density, the air no longer delays the heat loss by reradiation during intervals of darkness and cloudiness; snow and ice eventually supervene, and the hottest sun cannot reach the energy-trapping rock base through this reflecting surface.

Nevertheless, where the concentration of winds or the angle of slope prevents the accumulation of snow, surface temperatures above freezing may be expected at enormous altitudes. Certainly the Everest spiders bear this out: they were not frozen at 22,000 feet. Icicles hanging from rock faces at even higher elevations confirm the fact that thawing temperatures do occur. Climbers have told of experiencing uncomfortable warmth at great altitudes. Jung Marmet and Ernst Schmidt, who climbed Everest in 1956, actually removed their down-filled clothing because of the heat at an altitude of 28,000 feet. Such conditions can only prevail in sunshine and when the wind is reduced, but they are not infrequent on mountain summits. Photographs made on the summit of Everest by Sir Edmund Hillary in 1953 and Adolf Reist in 1956 (one of two men of the Swiss expedition to reach the summit) reveal a snowless expanse of rock and scree on a gentle slope only a few feet from the highest point. It is interesting to speculate whether springtails could survive here. There would in all likelihood be some organic debris even in this outermost part of the earth, and temperatures above freezing on occasion in some favored, wind-sheltered cranny might well occur. If springtails could not survive for lack of moisture, perhaps fungi or fungus-like bacteria, acting on microscopic quantities of pollen, may be present.

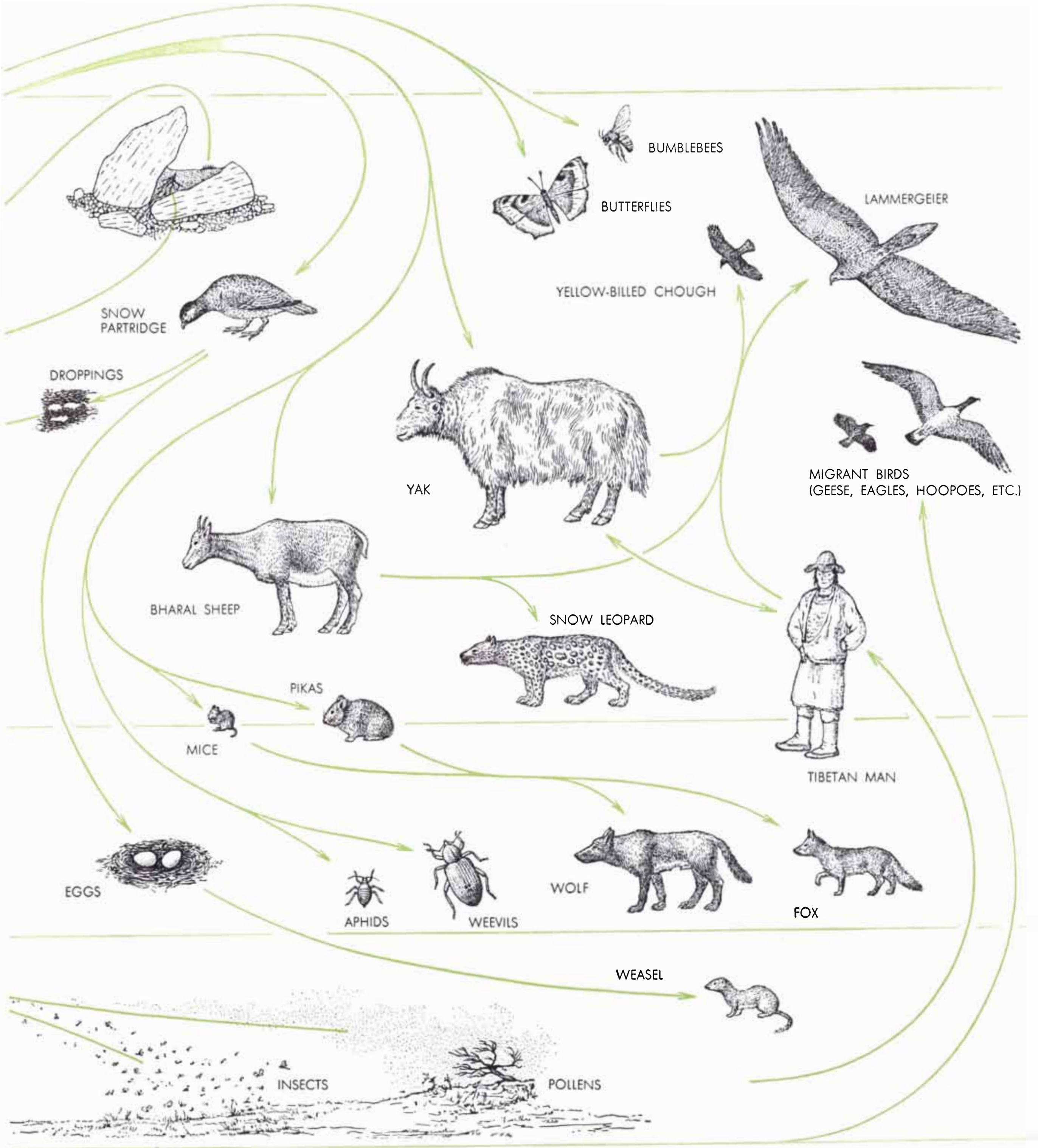
Barren and hostile to life as the aeolian province appears, a more forbidding environment is that which is presented at lower altitudes by the freshly cut rock rubble that covers a glacier. Here the angular slabs move and tumble, leaving gaping chasms and black voids between the boulders. A resting bird or an occasional transient fly seems to come from another world where there is life. Terrestrial man, when he dares to enter this domain, moves slowly and dangerously. It is a place to shun.

In just this sort of ungenial wasteland I was astonished to find at altitudes between 17,500 and 19,000 feet some large and active insects that are apparently confined to this incredible niche. They were dark-colored glacier fleas (*Machilanus*) belonging to the family Machilidae in the order Thysanura. Machilids are supposedly scavengers; this species could live, therefore, on wind-blown debris. They would sun themselves on the rocks until approached, and then, by strong flexing movements of their bodies, they would leap in random bounds to avoid capture. Time and again they would fall off the rocks and disappear into the dark gulfs deep in the glacier. It seemed as if they could never return to the surface.

It is curious that the animals that survive in the most inhospitable places and are pioneers in the zones beyond plant life are members of the orders Thysanura and Collembola, the oldest and most primitive insects. Perhaps there is a distant analogy between the highest altitudes and the sterile land



ECOLOGY AT HIGH ALTITUDES in the Himalayas is outlined. With obvious exceptions, arrows indicate ecological relationships; broken arrow, one assumed to exist. Arrows lead



from organisms that are fed or preyed on by the organisms to which they point except in the case of "Tibetan man" and the "Yak," whose relationship is mutually beneficial. Above 19,500 feet the organisms within the light dotted line are permanent residents.

of the Silurian period, when air-breathing arthropods evolved from their aquatic ancestors. These same primitive insect types may have been among the vanguard of animals on land, and it may be that the first land animals fed on the wind-blown debris that accumulated among the barren rocks of the world beyond the fringe of shore plants.

There is also an analogy between high altitudes and the deep sea. Both environments range beyond the limits of photosynthetic plants, and the inhabitants of these opposite realms survive on debris. Estimating on the basis of the abundance of life, it would seem that the ocean bottom, with its efficient gravity feeding system, is less hostile than the dry and frigid peaks that are provisioned by wind.

LAMMERGEIER (*Gyptaëtus barbatus*), seen here with a fledgling, is one of the largest flying birds. A scavenger that resembles both eagles and vultures, it is found in mountainous regions from the Pyrenees to northern India. Photograph was made by Eric Hosking.

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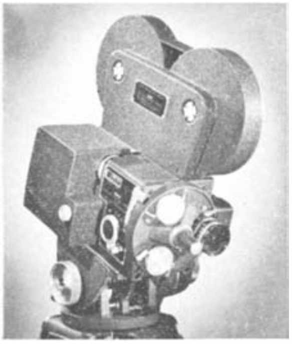

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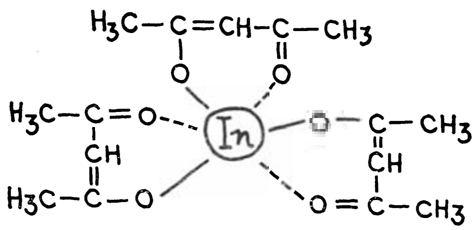
A speculation in indium



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