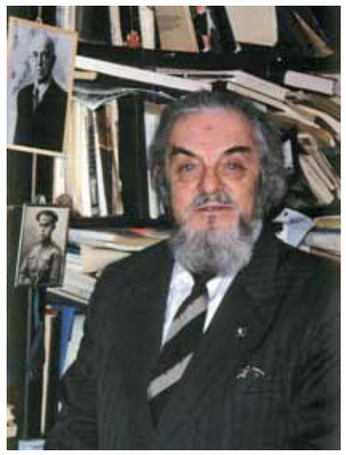
I.V. STEBAEV

Grasshopper *dear*

Evolution and ecology essays



For many years Doctor of Biology, Professor Igor V. STEBAEV taught zoology of invertebrates and biosphere ecology at Novosibirsk University. He studied the ecology of Acridoidea and grasshoppers residing in Siberia and adjoining areas, from Lake Issyk Kul in Central Asia to Lake Hanka in the Russian Far East. Prof. Stebaev has written many scientific and popular science articles and monographs

Grasshopper dear, oh, how blissful must it be…
This line belongs to the scholar and poet who separated the Literary Russian language from the Church Slavonic one and whom Aleksandr Pushkin called "our first university", Mikhailo V. Lomonosov. The verse about the grasshopper was composed during one of his trips from St Petersburg to Petergoff (a summer residence of Russian tsars), where Lomonosov would go for an audience with the daughter of Peter the Great to entreat with her of the privileges of the Imperial Academy of Sciences. The scholar's carriage was damaged and, while it was being repaired, the naturalist whiled away the time on a forest meadow grown with very high grass. It was a sultry summer day in August 1761, and the meadow brimmed over with the buzzing, chirping and singing of grasshoppers and other similar music-making creatures. Curtained off from the entire world by this concerto, Mikhailo rummaged through his knowledge on the subject and completed the verse:

To spend one's life in meadow, blithe and free!
These grasses, soft and long, are the abode you cherish
And honey dew is the repast you relish.
Though some may think you are a lowly creature,
You lead a royal life so few of us can feature.

Angel in flesh—no, rather you are fleshless!
Hopping and chirping, carefree and careless.
At home everywhere—and you have no fetter,
Nobody's drudge and no man's debtor…

Possibly, the main performer in the concerto the meadow played for Lomonosov was the genuine grasshopper whose sonorous Latin name is *Tettigonia cantans*, or song-grasshopper. This grasshopper, common in our moderate climate, comes to life in spring from an egg laid in the ground. Though it has long antennae and its jumping legs are almost as well developed as those of an adult insect, the creature is referred to as a grasshopper *nymph*: its abdomen and, above all, its wings are too short yet.

The nymph is yet to grow and moult, losing its old inextensible coat and putting on a new one, in a bigger size. Adult and fully grown insects are called *imago*, which means "the complete image of a being". When a nymph leaves the egg, it looks very much like an imago. This line of insect development is called *hemimetabolism* as it has no true wormlike larva, to say nothing of chrysalis, in contrast to other insects, for instance, butterflies.

The people who are not entomologists often call the acridoids, close relations of grasshoppers, "grasshoppers". Together with crickets, cockroaches, mantis, walking-sticks, and termites, they belong to the order of Orthoptera. In contrast to Paleoptera (dragonflies, for example), the Orthoptera's wings fold along the body and feature thickened and elongated veins, which protect the insects against a loss of moisture.

In grass labyrinth

The Acridoidea began to spread from the forests together with the grass, similarly to herbivorous hoofed mammals, only some 35—40 million years ago, in the middle of the Tertiary period, which was right before our Quaternary period.

Let us say a few words about the grass that appeared at that time—its growth was stimulated by the disaster suffered by trees, and the grass gave the Earth a second, invigorating breath. The disaster that had affected the trees was that seasonal climatic changes were becoming increasingly sharper, and the trees lacked time to bring fruit every year. Also, because of their long life, they failed to survive in the areas where the soils were washed off, whereas soil erosion became frequent as new mountain slopes were being formed: back at that time, mountains of the so-called Alpine generation were forming.

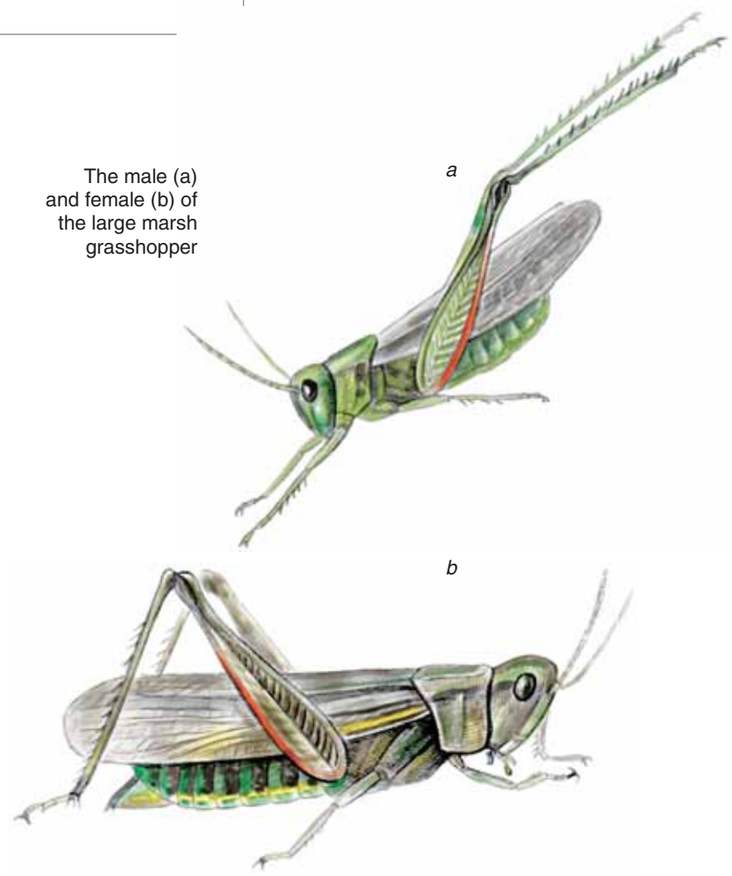
Living a shorter life, the herbs not only overcame the problems that suffocated their dendroid relatives but also contributed to a faster, yearly fertilization of soils with soft and easily decomposable mass of leaves and stems. The soils were thus enriched with organics (forest soils are podzolic, lacking humus and many chemical elements washed out by water; similarly to cinder, they are mainly rich only in silicon). In this way, the soils became a common reserve of

In contrast to the Orthoptera, butterflies and many other insects, starting from bugs, underwent the so-called "promising" catastrophe of their embryonic intra-egg development, or desembryonization. This happened no earlier than 320 million years ago and might have been caused by the insects' consumption of biologically active substances that the plants secreted to protect themselves against the insects.

The embryos hatched less and less developed and viable, and increasingly more resembling their remote evolutionary ancestors down to the worm-shaped ones—like the caterpillars, for instance. Hypothetically, this was the reason why such embryos managed to survive: they began feeding themselves on leaves and accumulating fat in their bodies, which replaced the egg yolk gone. The well-fed caterpillars and suchlike larvae could then afford a rest during which their interior transformations changed them to chrysalises — in fact, a second dormant egg.

In a chrysalis, the embryos of the future organs of an adult insect start developing from anew, and the caterpillar's tissues kind of dissolve to supply building material for the imago's organs. Thus, destruction of the first-stage life regularly brings forth a new life, flying out of the chrysalis in the shape of bugs, butterflies, flies, and other insects that go through this sophisticated and in many ways yet mysterious *complete transformation*, or *metamorphosis*

The outstanding Russian entomologist and ecologist G. Ya. Bei-Bienko (1903—1971) worked in Omsk, then in St Petersburg, in the laboratory of North Asian Insects' Studies with the Museum of the Zoological Institute, Academy of Sciences. He laid a foundation for the studies of the grasshoppers and Acridoidea of Siberia



The male (a) and female (b) of the large marsh grasshopper

The miracle of trees' transfiguration into grass resembles the miracle of desembryonization of insects' larvae, which we mentioned above. Here too, vital functions are transferred to the "youth"—in other words, *juvenilization* takes place. All the green mass (most importantly, blossoms and seeds) become to be quickly produced by the trees' undergrowth, which has not developed a dense trunk yet. The plants' life gets shorter but more colorful and diverse, as may be seen from blossoming meadows. During the warm season, grass has enough time to produce offspring, which rests in the soil in the form of seeds, and quickly weave a thick carpet over the forest clearings. Also, they manage to weave new, sun-bright vegetation covers for forest meadows, glades, steppes, and sometimes even deserts

nutrients for all the plants growing on a meadow, whereas each tree had such a reserve only in its own trunk. It is not by chance that meadows and steppes, especially in the black earth belt, were the motherland of cattle-breeding and agriculture, without which no modern civilization including hi-tech would be possible.

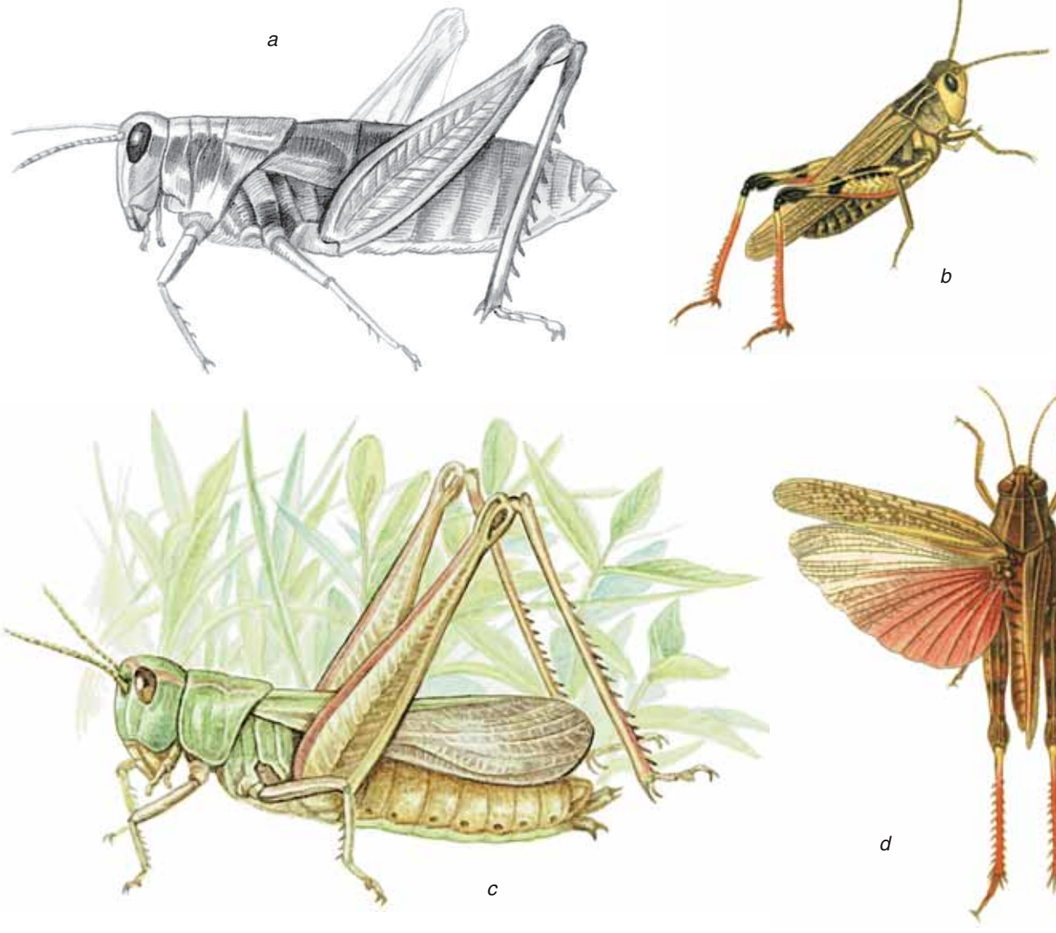
Herbivorous ungulates had appreciated the new developments long before the humans did. And they sometimes made a better use of them, too, regularly changing pastures so that the grass could grow again rather than turning steppes and meadows into trampled down patches one can see near villages.

The acridoids appeared to be "microungulates"—may be it is not by chance that they are called *kobylki* (Russian for "mares") and *kon'ki* (Russian for "horses") in common speech—with the only difference that they need no water. They take water from herbs and evaporate it through the surface of their bodies, which cools them down and protects against the heat—as they move round the Earth towards the sun, covering thousands of kilometers of grassy areas, decorating them with their attire and filling them with their songs.

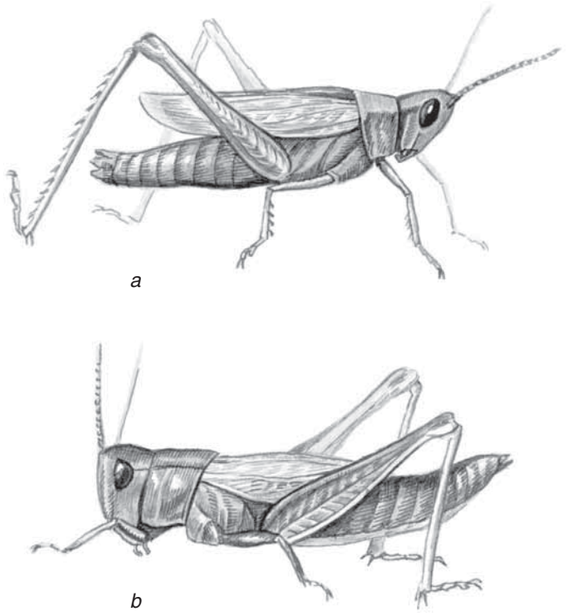
The name "Kobylki" normally applies to quite big Acridoidea that have a moderately elongated body round in its cross-section and an egg-shaped head. Similar insects used to leave the forest in the Tertiary period and adjust to living on glades, meadows and meadow steppes. As a rule, Kobylki stay in the lower part of the grass but mainly walk on the ground, preferably at the foot of the plants, strewn with fallen stems. If Kobylki land onto bundles of grass upon a jump, they hurriedly go down

Children of the sun

The Acridoidea's chase for water found in leaves and stems earned them the reputation of gluttons. Actually, their voracity in eating translates into modesty in consumption because, apart from water, they soak out of their vegetable diet only easily digestible, soluble substances like sugar and starch. Their inner digestion system is weak whilst mechanic processing of leaves is powerful, as it can be judged from their well-equipped upper jaws: one such



Kobylki: a) Podisma; b) Arcyptera fusca; c) Stenobothrus lineatus; d) Calliptamus italicus



Kon'ki: a) meadow pipit; b) brevipennate

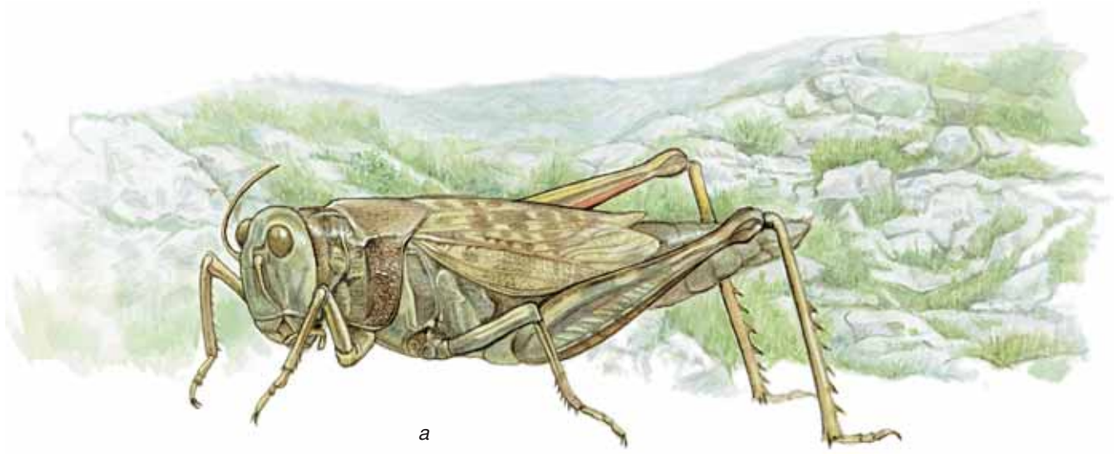
The Kon'ki, upon landing onto the ground, hasten to climb up a grass, and try to jump from leaf to leaf, doing their best to avoid the earth, especially if it is bald. Such habits tell on their looks: their body is squeezed at the sides and the head has the shape of an acute-angled triangle. Such configuration makes it easy for them to get through the thick forest of grass stems

jaw has flat incisors, resembling those of a horse, which are designed for biting, and strong flattened parts, which correspond to molars and are used for grinding pieces of leaves bitten off.

As a result, digested mass in acridoids stomachs, instead of becoming less nutritious, becomes even richer thanks to the nutrients hidden inside the plants' cellulose plasmic membranes and, therefore, not easily accessible for microorganisms. Nitrogenous matter is released from the plant tissue that has been ground with teeth. This is a blessing for nitrifying bacteria—it takes them a few hours to complete the decomposition of leaves into chemical elements, which, by the way, serve as an important fertilizer for the grass.

This is why the fibrous spindles of excrements the Acrididae drop from their stomachs to the earth are the gold coin they pay the grass for the treatment. Thanks to the bacteria cohabiting with the Acrididae, these spindles are also enriched with vitamins B, which stimulate grass growth and emergence. In this way, orthopterous Kon'ki and Kobylki appear to be grass cultivators rather than destructors.

Altai Bryodema, one of the Acrididae "tortoises": a) female; b) male



But what about the Acridoidea's bad reputation for the damage they inflict on the fields? Actually, many Acridoidea avoid living there permanently, preferring patches grown with weeds, which they "weed out" noticeably. On the virgin land surrounding a field they invariably choose a few species of wild-growing plants. Only when these plants lack, for instance, if a pasture has been trampled down by cattle, and search for the necessary plants takes too much time and effort, the acridoids may suddenly change their diet. Then they look for a replacement for their natural food on arable fields, which makes their life easier as the replacements are there, planted by people as if especially for the insects.

In this way, the Acridoidea, this progeny of the Sun, happen to be its helpers in enriching the biosphere.

Ways and walks

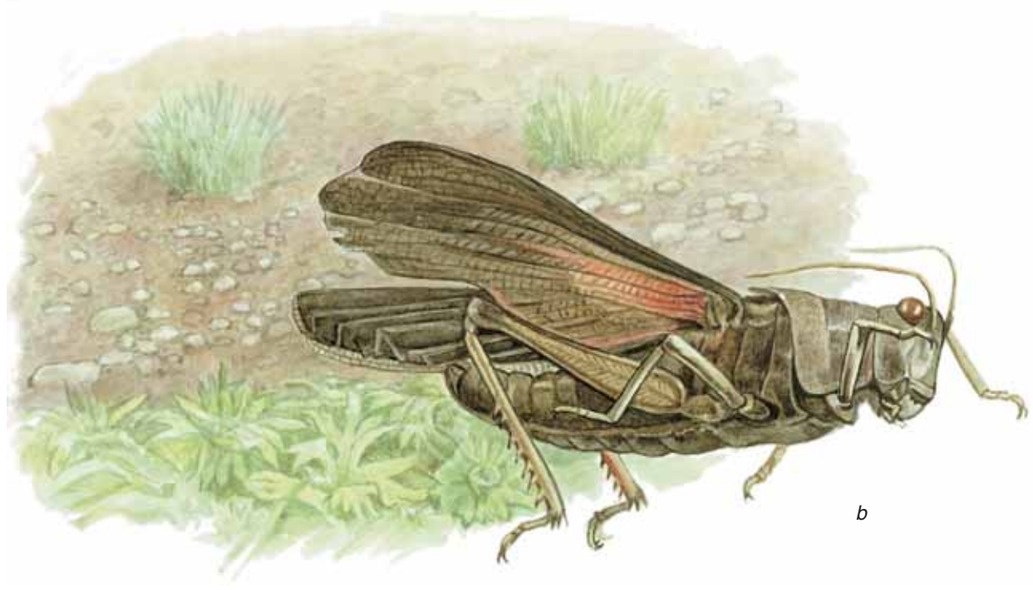
As we have seen, the acridoids live their life skillfully and even sensibly from the point of view of ecology. Therefore, let us have a closer look at the way they spend their life and behave in "these grasses, soft and long".

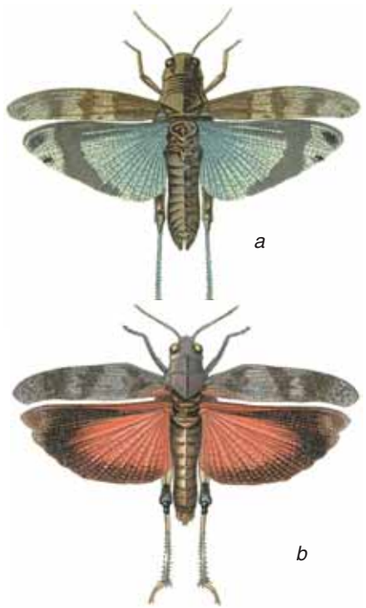
The best way to study the ways and habits of the Acridoidea is to turn into Tom Thumb, that is, to kneel before the grass and its inhabitants and to have a store of white pebbles. Now let us find a Kobylka and follow its path leaving pebbles along. We will need some patience, of course—similarly to Jean Henri Fabre, who investigated the instincts and ways of the insects—as our grasshopper sometimes has a snack or takes quite a long rest, leaning on its side and enjoying the sun.

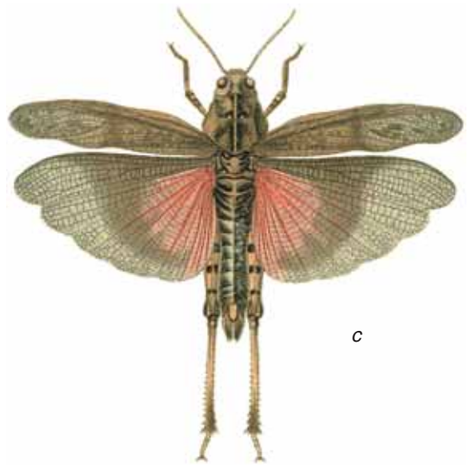
Having taken such a walk in thick grass, you will notice that the Kobylka chooses a winding path. At its every twist, however, it takes the shortest way to its favorite patch of land, bare or covered with a mattress of fallen leaves or herbs, or to the shady umbrellas of a certain plant. This is the way somebody who likes only apples or only pears would behave in a mixed orchard when he tries to fill his basket with fruit as quickly as possible with a minimum effort. On top of that, a Kobylka has to make its way so as not to be spotted by birds. Each species of the Acridoidea possesses its own skills and walks which make its representatives recognizable even if you fail to meet them personally.

The author of these lines together with his students put marks of paint on the backs of hundreds of the Acridoidea of two species, the meadow and the steppe ones. After that we let them go out of a net in the same place. This place was in the center of a spotted meadow, a hectare in area, which was turning into a steppe. We would then comb this meadow every day and count the marked insects found within the squares outlined by ropes stretched on the ground (the area of each square was 20 x 20 centimeters) in order to study how the insects settled. They appeared to move without a stop but not without an aim. The steppe species would find shortcuts to the steppe spots through the meadow spots, and the meadow species would do the opposite. The insects would cross alien paths quickly while take their time when they were on their native patches, moving along them, rather than across them. We would probably behave similarly in the rain: running hurriedly across a wet street and moving at leisure along a dry sidewalk.

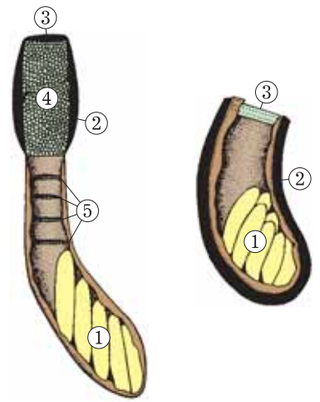
Day after day, the steppe inhabitants would move towards the most elevated and driest corner of the meadow,



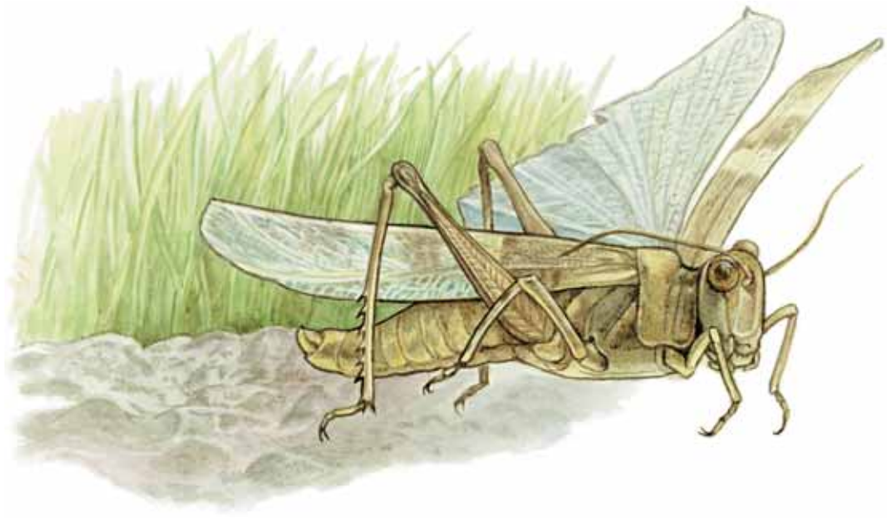




Acridoidea “tortoises” from various deserts:
a) blue-winged; b) red-winged; c) schochi



Egg cups with stoppers belonging to the Moroccan locust (on the left) and species living in moderate (on the right):
1— eggs;
2 — earthy walls;
3 — stoppers;
4 — foamy mass;
5 — filmy partitions



Hyalorrhipus clausi Kitt. Males of some species are exceptionally good fliers—they feature long wings, which make them look like little crocodiles on the earth when their wings are folded

The tortoises—as we arbitrarily call them—is a third large group of the Acridoidea which, in contrast to other Orthoptera, bravely conquer desert-like landscapes. Their short and broad bodies are flattened from below, and their heads are box-like and flat-faced. The body section looks like a semi-circular loaf of bread. Note that such body shape helps to cast almost no shadows on bare ground. Thighs of the hind legs are very thick, which allows them to make long leaps in open landscapes. Their earthy coloring makes them invisible in the desert, where other animals have nowhere to hide. Having landed after a leap and a flight, they run away from plants and stick to the bare earth surface comfortable to them — though they feed on leaves

where they had a better chance to come across spots of steppe vegetation. The other species would roll down to the low lying end of the test field.

This means that the acridoids not only scurry around sensibly but can orient themselves at long distances (probably, basing on the relief) and make their routes foreseeing the future, to a certain extent.

Also, we have found out that the Acridoidea, normally born on warm, dry hills, where spring comes first, gradually shift to the hollows, where spring comes later, as summer progresses and grass comes out and then burns out. In other words, this purposeful motion enables them always to live in spring. In the fall, the Acridoidea return to their native patch. This looks like a miniature migration of wild ungulates living in the steppe and traveling hundreds of miles. It goes without saying, that these ways and habits differ from species to species and, in their turn, affect the insects’ appearance.

Salutary swarms

The Acridoidea live in swarms—which somewhat resemble termites’ communities - like with termites, this is connected with laying eggs. The point is that the acridoid female, same as that of a grasshopper, receives the male’s spermatophore. It is inserted deep into the female’s body, and a few males can take part in this process simultaneously. The female normally lays eggs not into the moist and soft soil as the grasshoppers do but inserts them into the dry and hard earth using her ovipositor.

As it is hard for the female to “drill” a hole deep into the earth, where the soil is moister, she does her best to lay as many eggs as possible in one go. She secretes a special kind of mucus that mixes with loam to form a sort of a clay cup, inside which a whole pack of eggs is found corked with intricately designed porous stoppers. Moreover, while making such an incubator cup, females of some species with a strong gregarious instinct give off special volatile substances that signal other females that the soil is good for “drilling”. The other females hasten to lay their cups nearby—as a result, Acridoidea nymphs hatch in hordes.

At the same time, such stocks of big eggs are a great temptation for parasites like the *Meloidae* larvae, which penetrate into the earth through cracks.

The newly-born Acridoidea swarms often lack vegetative food. In this case, they develop the so-called *group effect*—without any intraspecific struggle for life—an example of coordinated communal feeding, which makes for the salvation of the community including its progeny. The group effect starts from the transformation of the Acridoidea nymphs. Now, they not only keep together, side by side, but “march” in bunches in the same direction. After that, they change their ordinary shape and coloring.

The mystery of the group effect was unraveled by the biologist Boris P. Uvarov (1889—1970). A Cossack from the Urals, he graduated from St Petersburg University and studied the acridoids inhabiting Russia and the Near East. Uvarov founded the International Research Anti-locust Center in London, which made predictions about the flights of these insects (to this end, the scientists used radars, which had recently come into being). He was awarded the title of baronet for his merits and, as a result, dropped his family name and became just Sir Boris, as is usual with the Brits

Interestingly, to achieve this, they have to move around a lot, see and touch one another.

The scientists have managed to convert a single insect into the gregarious phase by making it move round the running wheel towards a window of light that kept rolling back. Later it was found out though that, in order to achieve this transformation, the insects had to breathe in the same air.

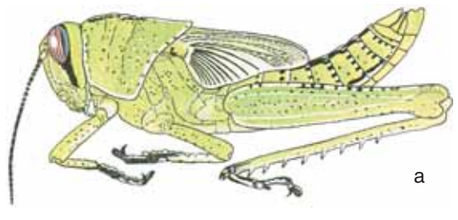
The group effect has been observed in some other insects like the Siberian silkmoth, whose caterpillars crawl towards one another to complete their individual transformation, that is, to develop into butterflies. Except insects, no other land animals have manifested the group effect. On the opposite, the intraspecific social, or *population, stress* is widely spread—disorder in the body's physiological regulations (especially typical of rodents)—which may even result in the males killing one another and the females destroying their own progeny.

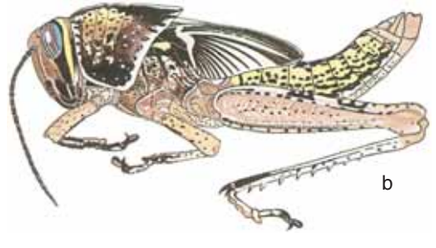
The atmosphere inside an acridoid bunch should be rich with exhalations of the insects—their *exohormones* ("exterior" hormones), to be more exact, which have been shown to influence even the chromosomes of the Acridoidea gametes, increasing the variability of their progeny. It is of interest that similar changes in the Acridoidea looks may be achieved by a mere increase in the dioxide gas concentration of the air inside the bunch.

In such a situation, the Acridoidea acquire some elements of management of their own genetic fund no other animals have yet displayed. Let us emphasize again that underlying these transformations is a change in the behavior of actively communicating insects.

Bunches of Acridoidea develop wings, rally and leave. The grown-up individuals spread their wings and fly off, as if at a command, away from the places where they were born. After their departure, there is enough food for the few insects that stay behind. The leaving swarms look for new pastures and, as though carried away by traveling, reduce their reproduction rate to one-third or one-forth. At the same time, such flights give rise to colonization of new, sometimes overseas, areas.

Nymphs of one kind change the colouring at transition from a single condition (a) to the gregarious one (b). *Picture by: (Popov, 1989)*





And finally

We can now say that the Acridoidea, having made a historic step from wet and shady to sunny places, have learnt to make a good and peaceful use of the grass and even to grow it by fertilizing the soil. Their entire being is the apotheosis of life after the grass has squeezed out the trees and, having formed black earth soils, opened up new horizons for the biosphere.

Mikhail Lomonosov has not only managed to stir up our interest in listening to the chirping of grasshoppers, as well as in their ecology and etology, but also has shown us something Fedor I. Tiutchev (1803—1873) expressed as follows:

Nature is not what you think,
Not an imitation or a soulless face—
No, it has soul and it has freedom,
It has love and it has a tongue.

We have come to these conclusions just having had a closer look at grasshoppers and their relatives. Without doubt, there are other guides to the amazing world we are so lucky to live in. The skies abound with dragonflies, flowers with butterflies, ponds with bugs, and soils with originally wingless insects. It is worthwhile to benefit from this in order to find out about the huge and remarkable Biosphere, which still has lots of secret corners waiting for us.

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